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A

MANUAL OF FORESTRY.

VOLUME I.

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INTRODUCTION TO FORESTRY.

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BY

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SECOND EDITION, REVISED AND ENLARGED,

CONTAINING A NEW PART ON "THE STATE IN RELATION TO FORESTRY,"
AND A
GENERAL REVIEW OF THE TIMBER REQUIREMENTS OF THE BRITISH EMPIRE.

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PREFACE TO THE SECOND EDITION.

THE first edition of the Manual of Forestry was divided into the following five volumes :

VOL. I.—THE UTILITY OF FORESTS, AND PRINCIPLES OF SYLVICULTURE.

„ II.—PRACTICAL SYLVICULTURE.

„ III.—FOREST MANAGEMENT.

„ IV.—FOREST PROTECTION.

„ V.—FOREST UTILIZATION.

The first three volumes were written by me, and they appeared in 1889, 1891 and 1895 respectively. In order to expedite the completion of the work, I arranged some years ago with my colleague, Mr. W. R. Fisher, that he should bring out as Volume IV. an English adaptation of Hess' Forest Protection, and as Volume V. a translation of Gayer's Forest Utilization. The former appeared in 1895, and the latter is now passing through the press. Thus my original task has been completed.

A second edition of Volume I. having become

necessary, I have thoroughly revised and in many respects enlarged it. More especially I have added a part on the State in relation to Forestry.

It is a matter of great satisfaction to me that this second edition has become necessary at an earlier date than I anticipated. The importance of forestry has more and more impressed itself upon the mind of Englishmen, and I trust that the remarks offered in the third part of this volume will further advance the cause of forestry in this country, in India and the Colonies.

W. SCHLICH.

COOPERS HILL,
28th February, 1896.

PREFACE TO THE FIRST EDITION.

THE present book is the outcome of circumstances, which it is desirable to explain :—

Although Forestry has been practised for centuries in Great Britain and Ireland, this particular branch of industry did not receive much attention in the United Kingdom until questions connected with the administration of the forests in India brought it into more prominent notice. In the latter country the condition of the forests began to be discussed in the early part of the present century, the first step having, apparently, been the establishment of a timber agency on the west coast of the Peninsula. Nothing more worth mentioning seems to have occurred until the year 1843, when Mr. Conolly, Collector of Malabar, commenced planting teak on a large scale at Nilambur. In 1847 Dr. Gibson was appointed Conservator of Forests in Bombay. In 1848, as the result of action taken by Captain Frederick Conyers Cotton, the Government approved of the appointment of Lieutenant James Michael as Forest Officer in the

Anamalais. Dr. Cleghorn's name is mentioned as early as 1847 in a report on the conservation of forests in Mysore, and he was ultimately appointed Conservator of Forests in Madras in 1856.

The first attempts at forest conservancy in Burma commenced soon after Tenasserim had become British territory in 1826, but nothing lasting or substantial was done until Lord Dalhousie took up the matter and, in January 1856, appointed Dr. D. Brandis (now Sir Dietrich Brandis, K.C.I.E.), Superintendent of Forests in Pegu. After seven years of exceedingly hard work in Burma, Dr. Brandis was, in December, 1862, placed on special duty with the Government of India, and in 1864 he was appointed to the newly created post of Inspector-General of Forests to the Government of India. He remained in this position until 1883, but was placed on special duty in Madras in 1881; he went to England in 1883, where he retired from the service shortly afterwards.

Those who preceded Sir D. Brandis prepared the way for the subsequent measures of forest conservancy, but it is the merit of that officer to have introduced into India systematic forest management as it is now understood in that country. When Sir D. Brandis first started operations, he had great difficulty in finding properly qualified assistants. He succeeded in securing the services of a limited number of good

officers who were mostly military men, but he had, at the outset, also to employ many men who were wanting in education. Accordingly, when he proceeded on furlough to Europe in 1865, he made it his business to secure a regular supply of trained forest officers. Under the arrangements made by him in 1866, a number of selected young Englishmen were sent annually for a term of two years and eight months to the Continent to study Forestry, half of them going to France, and the rest to Germany. Those of the students, who passed the prescribed examination at the close of their studies, were appointed to the Indian Forest Department as Assistant Conservators. The arrangements worked well at first, but gradually difficulties arose, in consequence of which the students were withdrawn from Germany in 1876, the whole number being concentrated at Nancy under the control of a special English officer.

About the year 1881 complaints were received as to the want of progress of the students at Nancy, and this led to the proposal for establishing a forest school in England, where the candidates for the Indian Forest Service might be trained. Colonel Pearson, then in charge of the English students, was foremost amongst those who supported this scheme. After a lengthy discussion Her Majesty's Secretary of State for India decided to start such a school in

connection with the Royal Indian Engineering College at Coopers Hill, and I was deputed in 1885 to organize the new branch of that establishment. My instructions went, however, further: they included the drawing up of Handbooks on Forestry. After upwards of twenty years' administrative work I found myself suddenly called upon to instruct in Forestry and to write Handbooks on the subject —a task which, I need hardly say, was beset by great difficulties. Although I had to some extent kept up with the progress of science while in India, I had now to commence earnest study in various directions. During the vacations I visited numerous forests in England, Scotland, Ireland, Germany, Austria, France, and Switzerland. Thus several years passed before I could venture to begin writing the desired books. That task I have now commenced, and, if I am spared, I hope by degrees to deal with Sylviculture, the Preparation of Forest Working Plans, Forest Protection, Forest Utilization, and Forest Finance. On all these matters I have collected notes, but the business of preparing them for the press will be the work of years.

In order to make at once available those parts which are ready, I have decided to bring out the work in a series of small volumes. Although the ultimate arrangement of the Manual may undergo some

changes as the work proceeds, my present intention is to divide it into the following parts :

PART I.—THE UTILITY OF FORESTS.
„ II.—FUNDAMENTAL PRINCIPLES OF SYLVICULTURE.
„ III.—CREATION, REGENERATION AND TENDING OF WOODS.
„ IV.—FOREST PROTECTION.
„ V.—FOREST UTILIZATION.
„ VI.—FOREST WORKING PLANS.
„ VII.—FOREST FINANCE.

Parts I. and II. are contained in this volume. Part III. will, I hope, appear early in 1890. Each volume can be purchased separately.

The information given above shows that I may fairly claim the indulgence of the reader. I do not pretend to have introduced into the work any special originality, but I have tried to arrange the matter as conveniently as possible, and to express myself as concisely as is compatible with clearness and completeness. The reader must judge for himself in how far I have succeeded in my task.

In conclusion, I desire to express my best thanks to my old Indian friends, Messrs. J. C. McDonell and W. R. Fisher, for their assistance in passing this volume through the press.

W. SCHLICH.

COOPERS HILL,
12th March, 1889.

TABLE OF CONTENTS

PAGE

PREFACE v

INTRODUCTION 1

PART I.

THE UTILITY OF FORESTS.

CHAPTER I.

DIRECT UTILITY OF FORESTS 14

1. Principal Produce, or Wood 14
2. Minor Forest Produce 15
3. Forests as Objects of Industry 16
   a. The Capital of Forestry 16
   b. Labour required in Forestry 24

CHAPTER II.

INDIRECT UTILITY OF FORESTS 27

1. Effect of Forests on the Temperature of the Air and Soil . . . 29
   a. Temperature of the Air 29
   b. Temperature of the Soil 35
2. Effect of Forests on the Moisture of the Air and the Movement of Water in Nature 37
   a. Humidity of the Air 38
   b. Precipitations, or Rainfall 40
   c. Evaporation 43

PAGE

3. Mechanical Effect of Forests 45
   a. Feeding of Springs and Rivers 45
   b. Protection of the Soil 46
   c. Protection against Avalanches 48
   d. Protection against Air Currents 48
4. Hygienic Effect of Forests 49
5. Æsthetic Effect of Forests 50

CHAPTER III.

SUMMARY OF CONCLUSIONS 51

PART II.

THE STATE IN RELATION TO FORESTRY.

Introduction 59

CHAPTER I.

DUTIES OF THE STATE IN REGARD TO FORESTRY 62

CHAPTER II.

PROTECTION FORESTS 67

CHAPTER III.

STATE FORESTS 71

1. Reasons for maintaining State Forests 71
2. Reasons against maintaining State Forests 74
3. Conclusions 75
4. General Principles according to which State Forests should be managed 75

PAGE

CHAPTER IV.

FORESTS OF COMMUNES, CORPORATIONS, &c. . . 78

CHAPTER V.

SUPERVISION OF PRIVATE FORESTS BY THE STATE 83

PART III.

FORESTRY IN BRITAIN AND IN INDIA.

Introduction 91

CHAPTER I.

FORESTRY IN GREAT BRITAIN AND IRELAND . . 99

1. Indirect Effects of Forests 99
2. Forest Produce required by the Nation 101
   a. General 101
   b. Land available for Afforestation 105
   c. Does Forestry pay in Great Britain and Ireland? 109
   d. Uncertainty of Future Supplies 112
3. Labour 114
4. Conclusions 115

CHAPTER II.

FORESTRY IN BRITISH INDIA 125

1. Physical Configuration of the Country 126
2. Climate and Rainfall 129
3. Distribution of Forests 140
4. Area of Forests 142
5. Forest Policy in India 144
   a. Forests in Relation to Climate and Rainfall 145
   b. Regulation of Moisture 146
   c. Forest Produce required in India 149
   d. Conclusion 151

PAGE

PART IV.

THE FOUNDATIONS OF SYLVICULTURE.

Introduction 157

CHAPTER I.

LOCALITY IN RELATION TO FOREST VEGETATION . . 162

SECTION I.—THE ATMOSPHERE 163

SECTION II.—CLIMATE 167

1. Heat 168
2. Light 174
3. Moisture 178
4. Air Currents 180

SECTION III.—SOIL 181

1. Origin of Soil 182
2. Formation of Indigenous Soil 182
3. Composition of Soil 184
4. Physical Properties of the Soil 189
5. Classification of Soils 191

SECTION IV.—EFFECT OF THE SOIL UPON FOREST VEGETATION . 195

1. Sufficient Depth 195
2. A suitable Degree of Porosity 197
3. A suitable degree of Moisture 197
4. A suitable Chemical Composition 198
5. Summary 201

SECTION V.—EFFECT OF FOREST VEGETATION ON THE LOCALITY . . 203

SECTION VI.—ASSESSMENT OF THE QUALITY OF THE LOCALITY . . 208

1. Assessment of the Locality according to its several Factors . . 209
2. Assessment of the Locality according to a Crop of Trees . . 213

PAGE

CHAPTER II.

DEVELOPMENT OF FOREST TREES . . . 216

1. Shape 216
2. Height Growth 219
3. Diameter Growth 223
4. Volume Growth 224
5. Duration of Life 226
6. Reproductive Power 229

CHAPTER III.

CHARACTER AND COMPOSITION OF WOODS . . 235

SECTION I.—PURE WOODS 235

SECTION II.—MIXED WOODS 237

1. Advantages of Mixed Woods 238
2. Disadvantages of Mixed Woods 240
3. Rules for the Formation of Mixed Woods. 241
4. Mixtures of Shade bearing Species 244
5. Mixtures of Shade bearing with Light demanding Species . . 247
6. Mixtures of Light demanding Species 257

CHAPTER IV.

THE SYLVICULTURAL SYSTEMS; OR, METHODS OF TREATMENT 261

SECTION I.—DESCRIPTION OF SYSTEMS 263

1. System of Clear Cutting in High Forest 263
2. The Shelter-wood Compartment System 266
3. The Shelter-wood Group System 267
4. The Shelter-wood Selection System 269
5. The Coppice System 271
6. Coppice with Standards (Stored Coppice) 273
7. High Forest with Standards 277

PAGE

8. Two-storied High Forest 278
9. High Forest with Soil-protection Wood 280
10. Forestry combined with the Growing of Field Crops . . . 280
11. Forestry combined with Pasture 283
12. Forestry combined with the Breeding of Deer and Game . . . 283

SECTION II.—SELECTION OF SYSTEM 284

A

MANUAL OF FORESTRY.

INTRODUCTION.

THE greater part of the dry land of the earth was, at one time or another, covered with forest, which consisted of a variety of trees and shrubs grouped according to the climate and soil of the several countries. When the old trees reached their limit of life they disappeared, and others took their place. The conditions for an uninterrupted regeneration of the forests were favourable, and the result was vigorous production by the creative power of the soil and climate. Then came man and interfered, not at once, but by slow degrees, until in the more civilized countries of the earth the area under forest was considerably reduced. But more than this: the creative power of the soil in the remaining forest lands had, through injudicious and careless treatment, become more or less impaired. Steps had then to be taken to arrest a further reduction of area; in many cases the forest had to be re-planted, and the original creative power re-established; thus a task presented itself, which forestry had to undertake.

What is now understood by that term did not spring into existence all at once, but was built up gradually, as necessity in various directions arose.

As long as forests occupied considerable areas, their produce was considered the free gift of nature, like air and water; man took it, used it, and even destroyed it without let or hindrance. Hence *Forest Utilization* is the oldest branch of forestry.

With the gradual increase of population, more land was required for the production of field crops, and this was taken from the forest area; reckless cutting and burning consumed more forest, until a time came when it appeared doubtful whether the natural woodlands could continue to yield the required produce for any length of time, if treated in the manner so far customary. This caused proprietary ideas to be developed; people claimed the ownership of certain forest lands, proceeded to protect them against outsiders, and thus the first signs appeared of that branch of forestry which is called "*Forest Protection.*" The protection, originally designed against man only, extended gradually to measures which had for their object the preservation of forests from injurious attacks by animals esp. insects, noxious plants in particular fungi, natural phenomena and other calamities.

By degrees it was found that mere protection was not sufficient, and that steps must be taken to enforce a more judicious treatment, and to limit the cuttings to what the forest was capable of producing; in other words, to determine the annual, or periodical, production, and to regulate the yield accordingly. Thus that branch which deals with the "*Preparation of Forest Working Plans*" sprang into existence.

Something more was, however, required. With increasing demand, it became evident that the ordinary natural regeneration could not keep pace with the rate at which the mature trees were removed. It became necessary to assist regeneration by artificial means, either by arranging the cuttings so as to favour and assist natural regeneration, or by artificial sowing and planting. Moreover, the young trees required special tending, in order to produce the most useful description of timber. In this way a fourth branch of forestry was developed, which is called "*Sylviculture.*"

As time went by, forests rose in value; they became articles of exchange or sale, and it was found necessary to devise a system for readily ascertaining their value. This produced another branch, which is called "*Forest Valuation*" or "*Forest Finance.*"

Originally, the protection which the owner of a forest could give to it was sufficient to guard it against mischief and interference. Subsequently this proved no longer sufficient, and the owner appealed to the State for help. It was also found that certain forest lands were of special importance to the community as a whole, either on account of their produce, or for climatic reasons, or on account of the protection which they yielded to adjoining lands. To regulate these matters the State had to pass certain laws, which are known as *Forest Laws and Forest Regulations.*

With the development of Political Economy, the forest question naturally was drawn within its province. It was asked, whether and in how far forests need be maintained in a country, whether the State as such should hold the forest lands, or whether the main-

tenance of forests might be left to private enterprise, and thus a further branch, called *Forest Policy*, was created.

The task, then, with which forestry has to deal is one of considerable extent; it may be shortly defined as follows:—

"To ascertain the principles according to which forests "shall be managed (Forest Science), and to apply these "principles to the treatment of forests (Practical "Forestry)."

The measures at first adopted in forestry have, with the advance of other branches of learning, been considerably elaborated. By degrees the teachings of general science have been brought to bear upon the subject, so that at the present day a fully competent forest expert must be acquainted with many branches of what may be called, from this point of view, auxiliary sciences. Amongst these may be mentioned—

Pure and Applied Mathematics.
Surveying.
Elements of General Law.
Political Economy.
Physics, including Meteorology.
Chemistry, Inorganic and Organic, including a knowledge of Soils.
Mineralogy and Geology.
Zoology, esp. Entomology.
Botany.

Of these, Botany is the most important branch, and its study should extend over Morphology, Physiology, and Systematic Botany with special reference to forestry.

The present object is to place before the reader an account of the more important branches of forestry.

Before proceeding with that task, it as necessary to explain a few terms which are used in the following pages.

The term "*Forest*" has been used above. Although most people know what a forest is, a definition of it, which suits all cases, is by no means easy to give.

In England a forest was formerly understood to mean an area which was stocked with deer; such an area was more or less covered with trees and shrubs, but not necessarily so. Thus *Manwood* in his treatise of the "Lawes of the Forest, 1598," defines a forest as follows:—

"A forest is a certain territory of woody grounds, fruitful pastures, privileged for wild beasts and fowls of forest, chase, and warren, to nest and abide in, in the safe protection of the King, for his princely delight and pleasure, which territory of ground, so privileged, is meered and bounded with unremoveable marks, meers and boundaries, either known by matter of record, or else by prescription, etc."

This definition has, in modern times, when the economic aspect of forests came more into the foreground, given way to others. Thus *Hundeshagen*, in the earlier part of the 19th century, understood by forest, an area which contains wild growing trees. This definition is not in all cases correct, because many forests,* which now exist, were artificially created, and sowing and planting may be going on in them at the present time.

Cotta, about the same time, defined a forest as an area

* Even the greater part of *Epping* forest seems to have been artificially created, especially the parts where hornbeam prevails.

which has been set aside principally for the production of wood, and which, for the greater part at any rate, is covered with trees. It may be objected, that many areas are classed as forest which do not contain trees, while others, like avenues and hedgerows, bear trees and produce wood, although they cannot be called forests.

These illustrations will suffice to show how difficult it is to draw up a general definition which suits all cases. The Indian Legislature, when preparing a forest law for India, decided, therefore, not to attempt a definition, but merely to provide that the Government may declare certain lands to be forests, and thus bring them under the operation of the Indian Forest Act.

In a general way, forest may be described as "an area, " which is for the most part set aside for the production " of timber and other forest produce, or which is expected " to exercise certain climatic effects, or to protect the " locality against injurious influences; such areas are fre- " quently subject to special forest laws and regulations."

Matters become easier when turning to the term *Wood*:—"By a wood, or woodland (plantation) is under- " stood an area of defined dimensions, which is stocked " with trees or shrubs, and managed for the production " of timber, firewood, and such other produce which " ordinarily accompanies the rearing of trees." Every wood is therefore a forest, but not every forest is a wood.

The difference between a tree and a shrub is not always easy to define. For sylvicultural requirements the following definitions will suffice:—

Tree means a woody plant, which, from natural

tendency, divides into two or more main branches at some distance from the ground.

Shrub means a woody plant, which, from natural tendency, divides into two or more main branches at or near the ground.

A tree may usefully be divided into three parts, the stool, the bole, and the crown :—

Stool means that part which remains in the ground after a tree has been felled close to the ground; it comprises the whole of the root system and the lower end of the stem up to the point where it emerges from the ground, or a short distance (generally a few inches) above the surface.

Bole means the stem, or trunk, of the tree from the ground to the point where it divides into a series of main branches. The lower part of the bole, which is free of any branches, is called the *Clear Bole*. In many cases bole and clear bole are identical.

Crown means the whole system of branches. In some cases, where side branches have been developed below the upper end of the bole, the crown and bole overlap each other.

A tree or shrub may start as a seedling, stoolshoot, sucker, or layer :—

Seedling means a tree or shrub which has sprung up from seed.

Stoolshoot means a shoot which has sprung up from the stool of a tree or shrub previously cut down.

Sucker, or *Rootsucker*, means a shoot which has sprung up from a root.

Layer means an undetached branch, which has been

bent down, partly buried in the soil, and which has developed roots of its own; it may subsequently be severed from the mother plant and develop into an independent tree or shrub.

With regard to the age of trees and woods, the following stages may be distinguished, when the trees have emerged from that of seedlings:—

Thicket means a dense crop of young trees from the time when the branches commence interlacing until the time when the lower ones begin to die and fall; a thicket is composed of *Saplings.*

Pole Forest means a crop of trees from the time when the lower branches commence falling (the bole thus clearing itself), until towards the end of the principal height growth; it consists of *Poles.*

Tree Forest means a crop of trees of which the principal height growth has ceased; it consists of *Trees*, or *Formed Trees.* Towards the end of this stage it is called a *Mature Forest or Wood.*

A further distinction must be made, in respect of the persistency of the leaves, between evergreen and deciduous trees:—

Evergreen Tree means a tree the leaves of which persist for not less than one year, so that it is never without leaves.

Deciduous Tree means a tree which is leafless for some time during each year.

Woods may be classified as follows:—

Pure Wood (or Forest) means a wood which consists of one species only.

Mixed Wood (or Forest) means a wood which consists of two or more species intermixed; the mixture can be arranged according to single trees or according to groups.

Again:—

Crowded Wood, or dense wood, means a wood which is completely stocked, so that the crowns of the trees interlace and form an uninterrupted leaf canopy, which thoroughly shelters the ground.

Thin Wood, or open wood, means a wood in which the crowns of the trees do not interlace, but form an interrupted leaf canopy, which only partially shelters the ground. A thin wood may be regularly or irregularly stocked.

For the sake of convenience, the produce which a forest yields is divided into principal or major, and into minor produce:—

Principal or Major Produce means timber and firewood.

Minor Produce means all forest produce except timber and firewood.

Increment means the material produced on a tree, or a given area, in a certain time; *Annual Increment* means the material produced in one year.

Growing Stock means the material actually standing on a given area at a certain time; it consists of an accumulation of annual increments from the creation of the wood up to a given time.

Rotation means the time which elapses between the formation of a crop of trees and its final removal.

Final Yield means the material obtained by the removal of the final crop, whether the removal is effected by one or by several successive cuttings.

Intermediate Yield means the material obtained by intermediate cuttings or thinnings.

The three principal sylvicultural systems, or methods of treatment, are represented by high forest, coppice forest, and coppice with standards:—

Seedling or High Forest.—The trees have sprung up from seed; they are permitted to grow up until they have reached the desired size, when they are cut over, and a new crop is started consisting again of seedlings; ordinarily the final cutting does not take place until after the end of the pole stage.

Coppice Forest, or Copse.—The trees consist of stool shoots or root suckers, which are cut over periodically, either close to the ground or at some distance from it, every succeeding crop being created in the same way.

Coppice with Standards, or Stored Coppice.—A combination of the above two systems: the forest consists of an overwood and an underwood; the latter is a coppice which is periodically cut over, the stools providing each time a fresh crop; the overwood consists of seedling trees, and occasionally of vigorous stool shoots, which are allowed to reach at least twice the age of the underwood, and are called the standards or stores.

Quality of Locality means the yield capacity of a piece of land according to the nature of the soil and the climate to which it is subjected.

These definitions will suffice for the present; all further terms will be explained as occasion requires.

PART I.

THE UTILITY OF FORESTS.

THE UTILITY OF FORESTS.

FORESTS are, in the economy of man and of nature, of direct and indirect value; the former chiefly through their produce, and the latter through the influence which they exercise upon climate, the regulation of moisture, the stability of the soil, the healthiness of a country and allied subjects. The effects of forests may be looked at from the point of view of the owner, or from that of the State. The owner considers, in the first place, the benefits which he personally derives from his forests; the State appreciates the effects which they have upon the country and the nation as a whole; hence, in the majority of cases, the owner is concerned chiefly with the direct effects, and the State with the indirect effects, or with both.

Each class of effects must be considered separately.

CHAPTER I.

DIRECT UTILITY OF FORESTS.

THE important direct effects of forests are due to the produce which they yield, the capital which they represent, and the work which they provide. The subject may be, therefore, divided in the following manner:—

1. *Principal Produce or Wood.*

Wood is used as *timber* in construction, shipbuilding, machinery, industries, agriculture, for tools, furniture, etc., and as *fuel* for domestic and industrial firing. The quantity of wood required in a country depends on various considerations, which will be dealt with further on. In modern times iron and other materials have to a considerable extent replaced timber, while coal, lignite and peat compete with firewood; nevertheless, wood is still indispensable and likely to remain so. The more general introduction of substitutes for firewood has, however, drawn increased attention to the production of timber in preference to firewood. For instance, of the total produce of the Saxon State forests, only 35 per cent. were classified as timber in 1850, but the proportion had risen to 75 per cent. in 1880. Similarly, in Bavaria it rose from 16 per cent. in 1850 to 33 per cent. in 1880.* At the same time new demands for the consumption of wood have sprung up,

* R. Weber in Lorey's "Handbuch der Forstwissenschaft, 1888."

such as the preparation of woodpulp for the manufacture of paper. It is estimated that the manufacture of the woodpulp imported into the United Kingdom consumes about 50,000,000 cubic feet of timber annually. Aspen firewood is now cut up for matches; beech, formerly the staple firewood, is used for furniture, floors, packing cases, pavements, wooden shoes, etc.

A part of the firewood is converted into charcoal or into ashes. Considerable quantities of the former are still used in domestic firing, iron smelting where a raw material of special excellence is required, in the manufacture of gunpowder, and for a variety of other purposes. Ashes are used for the manufacture of potash, or as manure.

2. *Minor Forest Produce.*

As all produce, which is not timber or firewood, is included under minor forest produce, it will be easily understood that the term comprises a great variety of articles, amongst which may be mentioned: bark especially for tanning, turpentine, resin, caoutchouc, gutta percha, catechu and numerous other dye-stuffs, leaves, flowers, fruits, seeds, fibres, grass, moss, peat, bamboos, canes, shellac, honey, wax and many others. Several of these materials play an important part in small farming, especially in poor countries, while others furnish the raw material for extensive industries. In order to illustrate the latter point it may be mentioned that Great Britain and Ireland import such articles of an estimated value of £8,000,000 a year.

3. *Forests as Objects of Industry.*

Forests occupy a certain portion of the earth's surface; hence forestry forms part of agriculture in its widest sense. They are important objects of industry, representing a large amount of capital, and they require labour in various ways, though at a rate different from that of other branches of agriculture.

a. The Capital of Forestry.

The capital employed in forestry consists principally of the soil and the growing stock of wood. When the working is of an intermittent nature, the amount of capital fluctuates from time to time; when the working is so arranged that an equal annual return is secured, the capital remains of the same amount and consists of the soil plus the permanently present growing stock.

The soil is called the fixed, and the growing stock the movable or shifting capital of forestry. The proportion of the one to the other depends chiefly on the method of treatment. In forests treated as coppice woods, the fixed may be greater than the movable capital, but in high forests, where the object is to produce timber of some size, the shifting capital is generally of considerably greater value than the soil. An example will illustrate this:—Assuming that an area of 100 acres is treated as a Scotch pine timber forest, under a rotation of 100 years, with the object of obtaining an annually equal return; in that case one acre must be stocked with 1 year old seedlings, another with 2 years old seedlings, another with 3 years old young trees, and so on to the last acre, which would be stocked with trees 100 years old.

Every year the oldest wood, 100 years old, is cut over and the area at once re-stocked. Immediately after the cutting 99 acres remain stocked with trees ranging in age from 1 year to 99 years old, and this is called the *normal growing stock*. Without the presence in the forest of this series of age gradations, it would be impossible to obtain a regular annual yield of trees 100 years old.

The subjoined table gives the capital invested in a forest worked upon the principle of a sustained annual yield. The data for the growing stock are taken from the Yield Tables* for the Scotch pine, by W. Weise, converted into English measures and arranged by the author. In calculating the value of the growing stock it has been assumed that fagots would not yield any net money return and that the timber, including all pieces of 3 inches diameter and upwards at the thin end, would realize 2 pence per cubic foot under a rotation of 30 years, gradually rising to 5 pence per cubic foot under a rotation of 120 years. Soil adapted for the growth of Scotch pine is generally light, and the value of such land of the I. or best quality cannot, on an average, be estimated at more than £25 per acre, while land of the III. or middling quality, may be estimated at £12 an acre, and land of the V. or lowest quality at £4, though land of the latter quality is frequently not worth more than a few shillings per acre:

* W. H. Allen & Co., Waterloo Place, Pall Mall, London, 1888, price 1*s*.

Length of Rotation in Years.	Capital Invested in Forestry—Pounds Sterling per Acre.								
	I. Quality, best.			III. Quality, middling.			V. Quality, lowest.*		
	Land.	Growing Stock.	Total.	Land.	Growing Stock.	Total.	Land.	Growing Stock.	Total.
30	25	8	33	12	2	14	4	1	5
40	25	17	42	12	7	19	4	3	7
50	25	26	51	12	12	24	4	5	9
60	25	35	60	12	17	29	4	8	12
70	25	45	70	12	22	34	4	11	15
80	25	56	81	12	28	40	4	15	19
90	25	68	93	12	35	47	4	20	24
100	25	80	105	12	42	54			
110	25	93	118	12	50	62			
120	25	106	131	12	58	70			

This table shows :—

(1.) That the capital increases with the length of the rotation.

(2.) That the value of the growing stock is at first smaller than the value of the land, equal to it under a rotation of from 40 to 50 years, and greater after that period. Under a rotation of 90 years, for instance, the proportion is as follows :—

	Growing Stock.		Land.
For the I. quality	2·7	:	1.
,, III. ,,	2·9	:	1.
,, V. ,,	5	:	1.

(3.) That the capital invested in timber forests is considerably greater than that of the land only.

The next table exhibits the yield which may be expected from Scotch pine forests growing on lands of the

* The above mentioned tables do not contain data for rotations of more than 90 years in the case of the V. quality.

I., III., and V. quality. The data have been taken from the above mentioned yield tables, and are based on the same prices as before. The yield represents the average return from final clearings and all thinnings, calculated for one acre per annum :—

Length of Rotation, in Years.	Total Yield (Final and Intermediate Cuttings) of Scotch pine Woods, per Acre and Year.					
	I. Quality.		III. Quality.		V. Quality.	
	In cubic feet.	In shillings.	In cubic feet.	In shillings.	In cubic feet.	In shillings.
30	87	15	29	5	12	2
40	120	23	58	11	24	5
50	132	28	69	14	32	7
60	137	31	74	17	36	8
70	137	34	76	19	38	9
80	135	37	76	21	38	10
90	132	40	75	22	36	11
100	129	43	73	24		
110	124	46	70	26		
120	118	49	67	28		

By comparing now the returns with the capital, the rate of interest at which the latter is working has been obtained and recorded in the following table, allowing 2 shillings all round per acre and year for current expenses :—

Length of Rotation, in Years.	Rate of Interest on the Invested Capital, in per cent.		
	I. Quality.	III. Quality.	V. Quality.
30	2	1·07	0
40	2·50	2·37	2·14
50	**2·55**	2·50	**2·78**
60	2·42	**2·59**	2·50
70	2·29	2·50	2·33
80	2·16	2·37	2·11
90	2·04	2·13	1·87
100	1·95	2·04	
110	1·86	1·94	
120	1·80	1·86	

This table shows:—

(1.) That the rate of interest obtained from the invested capital culminates under a rotation of fifty to sixty years according to the quality of the locality.

(2.) The higher the rotation beyond the culminating point, the lower the rate of interest.

(3.) Only in one case does the rate of interest appreciably exceed that obtainable from British Consols, namely on land of the V. quality, and then the excess is small; for the I. and III. qualities the maximum interest is about $2\frac{1}{2}$ per cent.

The data upon which these calculations have been based are not absolutely correct, but they represent the actual facts in certain cases. The value of the fagots, it will be remembered, has been omitted, because in many parts of England they are almost unsaleable, and at the outside they bring little over and above the cost of cutting and preparing them. On the whole then, on financial grounds only, the conclusion seems justified that all land which can be let for the raising of field crops, for shooting or other purposes, at a rental equal to, or upwards of, $2\frac{1}{2}$ per cent. of the capital value of the land, had better be so let. On the other hand, land which would realize a rental of less than $2\frac{1}{2}$ per cent. of its value, may with advantage be planted with Scotch pine, or other similarly remunerative trees. Land of the latter class has been designated as *absolute forest land.* The prices, on which the above calculation is based, have purposely been placed low; by substituting higher prices, a correspondingly higher rate of interest would be obtained. For further

details on this point attention is invited to part III. of this volume, and to volume III.

Apart from the purely financial aspect, there are other considerations which influence the investment, or otherwise, of capital in forestry. Of these the following may be mentioned:—

(1.) As a rule, forests do not require to be artificially manured, because trees take from the soil much smaller quantities of mineral substances than field crops. According to Ebermayer * an average forest crop, wood and leaves, requires annually about 54 per cent. of the mineral substances necessary for an average field crop. Of that quantity 46 per cent. are stored in the leaves, and 8 per cent. in the wood. It follows that, if the leaves are left in the forest, a crop of trees takes from the soil only one-twelfth the quantity of mineral substances which a field crop takes in each year; in other words, almost any soil can produce timber trees without being artificially manured, especially as the annual fall of leaves and mosses growing in the shade of the trees produce a thick layer of mould, or humus, which secures excellent physical conditions in the soil, rendering artificial working unnecessary. As a natural consequence, the better classes of soil are generally allotted to the production of field crops, and the inferior soils to forests.

(2.) The weather, natural phenomena, animals, and men, are sources of danger to the produce of the land. In the case of field crops only the produce of one or two years at a time is exposed to such dangers, but in

* "Physiologische Chemie der Pflanzen," first volume. Berlin. Julius Springer, 1882.

forestry the whole of the growing stock, or an accumulation of many years' produce, is constantly liable to be affected; on the other hand, a forest crop is, as a rule, less susceptible to damage than the more tender field crops. The greatest dangers which threaten the growing stock are those from fire, insects, and storms. A fire may destroy the whole of the growing stock, especially in coniferous forests; insects do often considerable damage by killing or injuring the trees, while storms may uproot at one time such large numbers of trees that the material becomes almost unsaleable, apart from the fact that young woods may be seriously injured, and the systematic management deranged for a considerable period.

(3.) Mistakes made in the cultivation of field crops can generally be rectified after the lapse of one year, while in forestry often long periods pass before this is practicable. If, for instance, the forester selects a wrong species for planting, he will probably not find out his mistake until many years afterwards, as most indigenous species do almost equally well on ordinary soil for a series of years; those unsuited to a certain locality will in most cases only commence falling off in growth some twenty or thirty years after planting. It follows that greater care and skill is required in forestry than in the cultivation of field crops so as to avoid initial mistakes.

(4.) Forest produce is a bulky article which does not bear transport, especially overland, to the same extent as the better classes of field crops. Hence the produce of forests must be consumed within a limited radius of the spot where it has been produced, unless water carriage is available.

(5.) The danger of trenching on capital is much greater in forestry than in other branches of agriculture. A farmer may to some extent reduce the value of his land by over cropping and under manuring, but this can easily be detected and rectified. In forestry the more valuable part of the capital consists of the growing stock, that is to say, material of the same class as that of which the legitimate annual return consists; hence an unscrupulous or ignorant forester can easily consume the capital, or at any rate a good portion of it, in the shape of annual income, without being detected or even becoming himself aware of the fact. In this respect, again, forestry requires greater skill and care than other branches of agriculture.

(6.) Forests, more than other lands, are burdened with rights (or servitudes) and privileges belonging to third persons. The right of property is either complete or limited. In the former case the owner can do with the property what he pleases, subject to the general laws of the country; in the latter case his power over the property is limited by rights of third persons. Such rights may be that the third person can take produce from the forest, or use it in certain other ways, as, for instance, for grazing cattle, or for sport. A forest right, or servitude, may be attached to a person, or to a piece of property such as a house, a piece of land, etc. In the former case it becomes generally extinct with the death of the person; in the latter it goes with the property from one legal owner to another. As a general rule, servitudes interfere much with the management and usefulness of the property. Though in many cases unavoidable, they are injurious

when looked at from the view of political economy; in most countries they are peculiar to forest property.

(7.) Finally, money cannot be borrowed on forest property to its full value. Generally only the land offers absolute security, while the growing stock is not only exposed to special dangers, but can also be considerably reduced by an ignorant or unscrupulous manager without much risk of discovery. For the same reason forests are not fit objects for letting.

b. Labour required in Forestry.

Forests require labour in a great variety of ways, which may be brought under the following three headings:—

(1.) General administration, formation, tending, harvesting, etc., or work done in the forests.
(2.) Transport of produce.
(3.) Industries which depend on forests for their prime material.

(1.) *General Administration.*—The quantity of labour required in the forests differs considerably according to circumstances, the value of the produce, and the consequent degree of minuteness of the system of management. Great difficulty is experienced in obtaining accurate statistics on this point, but five days' work annually for every acre of land under forest may be accepted as an approximate estimate all round. From the available data it has been calculated that in the forests of Germany about £8,000,000 are paid annually for administration, formation, preservation, road making, cutting of wood and collection of minor forest produce, on which about 200,000

families exist, or about 1,000,000 people. This estimate refers to forests which are already in existence, and in which fencing is done only in very rare instances. When new forests are created, additional labour is required at the outset. Nevertheless it is beyond doubt, that forests require only about one-tenth to one-twentieth of the labour necessary for land under field crops.

(2.) *Transport of Produce.*—Owing to the bulky nature of forest produce its transport forms a business of considerable magnitude. Timber and firewood are carried by water, whenever practicable, but also extensively overland. Under this head a sum of at least £4,000,000 is paid annually in Germany.

(3.) *Forest Industries.*—The labour which is required to work up the raw material yielded by forests is of a much greater extent than that employed in managing the forests and in transport. There are the workmen employed in saw mills, building, ship building, carpentry, coach building, engineering, turning, carving, paper pulp manufacture, match making, the manufacture of cases and boxes, round and square, from the largest packing case to the smallest toy box, frames of sieves, drum and cask hoops, wooden wire for table covers, blinds, pencils, wooden nails, instruments, tools, plates, shovels, spoons, shoes, lasts, saddle-trees, brushes, harrows, gun-stocks, toys of thousands of patterns, and endless other branches of industry, some of which can only exist in and around extensive forests. The wages earned under this head amount in Germany to something like £30,000,000 a year, maintaining about 600,000 families, or 3,000,000 people.

Taking now the three heads of labour together, it has been estimated that something like 12 per cent. of the population of Germany is employed in forest work, transport of forest produce, and the working up of the raw material yielded by the forests.

An important feature of the work connected with forests and their produce is, that a great part of it can be made to fit in with the requirements of agriculture; that is to say, it can be done when field crops do not require attention. Hence forest work offers an excellent opportunity to the rural labourer or small farmer of earning some money when he has nothing else to do, and when he would probably sit idle, if no forest work were obtainable.

CHAPTER II.

INDIRECT UTILITY OF FORESTS.

A PIECE of land which is bare of vegetation is, throughout the year, exposed to the full effects of the sun and air currents, and the climatic conditions which are produced by these agencies. If, on the other hand, a piece of land is covered with a growth of plants, and especially with a dense crop of forest vegetation, it enjoys the benefit of certain agencies, which modify the effect of sun and wind on the soil and the adjoining layers of air. These modifying agencies may be shortly enumerated as follows:—

(1.) The crowns of a full crop of trees provide a more or less dense roof at a certain distance from the ground, which intercepts the rays of the sun and the falling rain, obstructs the movement of air currents, and reduces radiation of heat during the night.

(2.) The leaves, flowers and fruits, augmented by certain plants which grow only in the shade of trees, form a layer of mould, or humus, which protects the soil against changes of temperature, and greatly influences the movement of water and air in the soil.

(3.) The roots of the trees penetrate into the soil in all directions and bind it together.

The effects of these agencies have been observed and recorded from ancient times down to the present, and hundreds of pages could be filled with the record of instances in which forest vegetation has affected, or has been believed to have affected, the climate, the

rainfall, the regulation of moisture, the stability of the soil, the healthiness of countries and allied matters; if quantity of evidence alone were wanted, the case might be considered as "proven." In all such cases, however, two or more agencies were at work at the same time, and the observations were not always sufficiently accurate and direct to decide, in how far the produced effect was due to the one or the other cause. The consequence naturally was exaggerated confidence and belief on the part of some, and doubt and unbelief on the part of others. This led in modern times to the commencement of accurate observations, first by Becquerel in France, and then by Nördlinger and Krutzsch in Germany, who recorded the effects of forests upon temperature and rainfall at stations situated in, or in the vicinity of, forests. A thoroughly practical and conclusive method was, however, not introduced until the year 1867, when Professor Dr. E. Ebermayer started so-called parallel or double stations, one being situated inside a fully stocked forest, and the other at some distance from its external boundary in the adjoining open country, all other conditions, such as elevation, soil, etc., being as near as possible the same in both cases. Ebermayer started seven double stations of this kind in various parts of Bavaria. Switzerland soon followed with three double stations in the Canton Bern; then Austria, Italy, Prussia, Alsace-Lorraine, Thüringia, Brunswick, Würtemberg, France, and others. About twelve years ago similar double stations were started in India (Dehra Dun, Berar, Ajmere). The result has been a rich crop of reliable observations, and although many questions await as yet a final solution, much has been

learned and established, which it is proposed to indicate in the following pages. The results of the Bavarian observations were published by Dr. E. Ebermayer in his excellent book, "Die physicalischen Einwirkungen des Waldes auf Luft und Boden," and Prof. Dr. R. Weber has subsequently brought together the more important results of all European observations in his Introduction to the "Handbuch der Forstwissenschaft," edited by Dr. T. Lorey, published in 1888. Observations made since 1888 have, however, considerably modified the conclusions drawn by Weber in the above mentioned work.

In order to concentrate the data into the smallest possible space, they have been arranged according to seasons in the following manner:

Spring	comprises	March, April and May.
Summer	,,	June, July and August.
Autumn	,,	September, October and November.
Winter	,,	December, January and February.

The subject of the indirect effects of forests will be dealt with under the following headings:—

(1.) Effect of forests on the temperature of the air and soil.

(2.) Effect of forests on the moisture of the air and the movement of water in nature.

(3.) Mechanical effect of forests.

(4.) Hygienic effect of forests.

(5.) Æsthetic effect of forests.

1. *Effect of Forests on the Temperature of the Air and Soil.*

a. Temperature of the Air.

The observations made at the double stations mentioned above have shown that forests, on the whole, slightly

reduce the mean annual temperature of the air. The general average of all stations has yielded the following results:

Decrease of mean annual temperature inside the forest, compared with the temperature at five feet from the ground in the open:—

At five feet above the ground . = 1·04° Fahr.
In the crown of the trees . . = ·41° „

The whole effect of a complete forest growth is, thus, a reduction of 1° Fahr. at five feet above the ground, and ·4° in the crowns; somewhat more than the average in mountainous countries, and somewhat less in the plains. Evergreen trees with a dense foliage, such as silver fir and spruce, have the most powerful effect, while deciduous thin-crowned trees exercise little effect. On the whole it is clear that there is a slight decrease of temperature from the region immediately above the crown towards the ground.

Of more importance than the mean annual temperature is the mean temperature of the four seasons. Here, as in all future cases, a reduction in the forest is represented as minus (−), and an increase in the forest over the outside station as plus (+).

Season.	Reduction of Temperature inside the Forests, in Degrees Fahrenheit, as compared with the Temperature at 5 ft. above the Ground in the Open Country.	
	At 5 ft. above the Ground.	In the Crowns of the Trees.
Spring . .	−1·24	− ·59
Summer . .	−2·54	−1·48
Autumn . .	−1·13	− ·41
Winter. . .	− ·61	+ ·05
Mean of Year	−1·04	− ·41

These data show that the difference of temperature is greatest in summer, smallest in winter, and that spring and autumn stand about half-way. As to the crowns of the trees, the temperature is even slightly higher in winter than that of the air outside.

It is of interest to follow the course of temperature during the twenty-four hours of the day. The following figures give the differences calculated from the Bavarian and Würtembergian observations :—

Season.	Differences of Temperature between Forest and Open Country at 5 ft. above the Ground in both cases, in Degrees Fahrenheit.			
	Minimum at Night.	8 A.M.	Maximum, Early Afternoon.	5 P.M.
Spring . . .	+ ·81	− 1·82	− 3·87	− 2·09
Summer . . .	+ 3·15	− 3·42	− 7·42	− 3·44
Autumn . . .	+ 2·59	− ·99	− 4·00	− 1·06
Winter . . .	+ ·95	+ ·27	− 1·96	− ·99
Mean of Year .	+ 1·87	− 1·49	− 3·91	− 1·89

It will be observed, that the temperature in forests is higher during the night and lower during the day, than on open ground; the difference is most pronounced in summer and next in autumn. This leads to the conclusion that forests tend to moderate the extremes of heat and cold. In order to illustrate this further, the following data are given, which show the extent of this action in July and January, ordinarily the hottest and coldest months of the year. The figures represent the averages of the Prussian observations made during ten years :—

Height at which Measured.	Difference of the Absolute Maxima of Temperature in *July*, Mean of 10 Years.	Difference of Absolute Minima of Temperature in January, Mean of 10 Years.
At 5 feet above the ground	− 5·87	+ 2·70

These figures show that the maximum temperature of forests, situated in a climate like that of Northern Germany, may be lowered in July by 5·87 degrees at five feet above the ground, and the lowest temperature in January may be raised by 2·70 degrees. The detailed observations of the different stations show further, that the above effect depends greatly on the geographical position, and the extent to which the localities are exposed to, or protected against, air currents. The effect differs also considerably according to species, as the following data will show: —

Species.	Reduction of Highest Temperature in July.	Increase of Lowest Temperature of January.
In Beech Woods . . .	− 8·37	+ 2·12
In Spruce Woods . .	− 4·61	+ 4·28
In Scotch Pine Woods . .	− 4·14	+ 2·12

Fully stocked beech forests reduce the extremes of the air temperature during July almost twice as much as spruce or Scotch pine woods; on the other hand during January spruce woods moderate the extremes of cold twice as much as beech or Scotch pine woods. This is due to the dense foliage of beech in summer and its leafless condition in winter; while the leaf canopy of Scotch pine woods is always much thinner than that of spruce woods.

The above data indicate that forests situated immediately to the north and south of the 50° northern latitude reduce the temperature of the air in their interior, which effect communicates itself to the surrounding country, owing to the continuous interchange of air between the two. The actual effect, it was thought, might be even somewhat greater than the above data

indicate, because many of the outside stations were situated so close to the edge of the forest that their temperature was already somewhat affected by an interchange of the air. This was indicated by the fact, that greater differences of temperature were observed in those cases, where the outside stations were situated at a great distance from the edge of the forest. With the view of arriving at more final results on this point a commencement was made in Austria to establish a system of so-called radial stations, that is to say, several series of points of observation which commence in the centre of a considerable block of forest, and are placed, in various directions, at fixed intervals, from the centre and gradually into the open country surrounding the forest. In this way it has been ascertained that the effect of forests on the temperature of the air in the adjoining open country is very limited.

Dr. Woeikof, Director of the Meteorological Institute at St. Petersburg, has published several series of figures, with the view of illustrating the effect of extensive forest areas on the temperature of the surrounding country. He gives the mean temperature of July for various series of places, each series being situated as near as possible on one and the same degree of latitude, after having reduced the data to the same latitude and an elevation of 656 feet above the sea. The following figures are those given for two series:—

MEAN TEMPERATURE OF JULY REDUCED TO AN ALTITUDE OF 656′, IN DEGREES FAHR.

On the 50th degree of Northern Latitude.		On the 38th degree of Northern Latitude.	
Guernsey	59·5	Lisbon	70·5
Brussels	62·6	Campo Major	76·3
Würzburg (Main valley)	68·0	Palermo	76·5
Promenhof (N. W. Bohemia)	64·4	Athens	79·2
Prague (centre of Bohemia)	68·0	Smyrna	77·9
Hochwald (Moravian plateau)	63·7	Lenkoran	74·7
Troppau	68·0	Krasnowodsk	82·0
Arvavaralji (N. W. Hungary)	64·2		
Lemberg	65·5		
Kiew	66·2		
Charkow	68·4		
Szemipalatinsk	72·7		

Dr. Woeikof points out that the temperature rises on proceeding from the Atlantic Ocean in an easterly direction to continental countries; indeed, there is a difference of 13·2 degrees between Guernsey and Szemipalatinsk, and of 11·5 degrees between Lisbon and Krasnowodsk. This on the whole steady increase of temperature is here and there interrupted, a phenomenon which is ascribed to the presence of extensive forests. He points out that on the 50th degree of latitude the first decided fall occurs at Promenhof, which has in its vicinity the extensive forests situated on both sides of the Bavaria-Bohemian frontier. Then at Hochwald the second fall occurs, a place which is situated close to extensive forests. Further east, at Troppau, the temperature rises again, but on entering the densely wooded valleys of the Hungarian Carpathians, a third depression of temperature becomes apparent. The comparatively low temperature in eastern Gallicia, at Lemberg, is also ascribed to the presence of extensive forests; while large forests and marsh lands are found close to the north-west and north-east of Kiew. As soon as the Steppes are approached the temperature rises rapidly. As to the places situated on the 38° of latitude it is

pointed out, that the temperature rises rapidly from Lisbon towards the interior until Athens is reached; at Lenkoran a decided fall is shown, ascribed to the presence of dense forests.

These and other similar data are very interesting and suggestive of certain effects on the temperature exercised by the presence of large forests; still, they should be received with caution, because it is impossible to ascertain in how far other circumstances may have produced the reductions, such as exposure to air currents, presence of large sheets of water, swamps, &c. Thus, large marshes are found at Kiew, while Lenkoran is situated on the banks of the Caspian Sea.

b. Temperature of the Soil.

As the temperature of the soil follows the temperature of the air near the surface in its upward and downward movements, it is necessary to observe the temperature at various depths. The following is an abstract of the Swiss, Bavarian, and Würtembergian observations :—

Season.	Differences of Mean Temperature of Soil between Forest and Open Ground, in Degrees Fahrenheit.				
	On the Surface.	At 1 foot below the Surface.	At 2 feet below the Surface.	At 3 feet below the Surface.	At 4 feet below the Surface.
Spring . . .	−4·45	−3·33	−3·17	−2·84	−2·43
Summer . . .	−6·89	−6·71	−6·80	−6·84	−6·64
Autumn . .	−2·29	−2·41	−3·02	−3·29	−3·64
Winter . . .	− ·20	+ ·41	− ·04	·00	− ·29
Mean of Year .	−4·14	−3·02	−3·24	−3·20	−3·17

The following conclusions may be drawn from these figures :—In the first place the differences in the mean

annual temperature of the soil are nearly the same from 1 foot below the surface down to 4 feet. Next, it is evident that the mean annual temperature of forest soil is decidedly lower than that of soil in the open; in summer by nearly 7 degrees, very little in winter, while spring and autumn hold positions half way. It should also be noted that in spring the temperature sinks from the surface down to 4 feet, and in autumn the reverse takes place, due to the fact that the changes of temperature at the surface of the ground are only slowly transmitted to the lower layers of soil.*

The effect differs considerably in the case of different species. In this respect the Swiss observations, average of 12 years, have yielded the following results:—

Season.	Difference of Temperature of the Soil Inside and Outside of Forests, according to Species.		
	Spruce.	Beech.	Larch.
Spring . . .	− 5·72	− 2·47	− 2·02
Summer . . .	− 9·18	− 6·43	− 4·88
Autumn . . .	− 4·10	− 2·99	− 2·56
Winter . . .	+ ·16	− ·16	+ ·59
Mean of Year . .	− 4·81	− 3·01	− 2·21

The evergreen spruce reduces the temperature of the soil considerably more than the deciduous beech, and still more so than the larch. This difference is very important in spring, that is to say, during the season when the trees commence the annual cycle of growth.

The above data seem to justify the following conclusions:—

(1.) The climate of forest countries is more equable than that of open countries.

* This follows from the actual temperatures, which are not given here.

(2.) The mean temperature of soil and air in forest countries is somewhat lower than that of soil and air in open countries.

(3.) The reduction of the temperature may act beneficially in hot countries, but it may be injurious in countries removed from the equator, where the temperature is already lower than is good for the ripening of field crops.

(4.) Vegetation awakens later in spring in well stocked forests, than in open ground.

(5.) As forests moderate the extremes of temperature, plants growing under the shelter of a forest crop are less liable to suffer from late and early frosts, or from drought, than plants growing in the open.

2. *Effect of Forests on the Moisture of the Air and the Movement of Water in Nature.*

Air can hold only a certain maximum quantity of vapour, which increases and decreases with the temperature. When the maximum has been reached, and more vapour is introduced, a part becomes fluid. The absolute vapour in the air is measured by its tension upon a column of mercury, as represented in a barometer. The proportion of the absolute to the maximum tension of vapour, which is possible at a certain temperature and pressure, is called the relative humidity of the air. Although the humidity of the air depends in the first place upon the general distribution of heat and air pressure over the large sheets of water on the earth, which govern the direction and force of the moist air currents, the vegetation of the earth must also affect the degree of

humidity, chiefly because it reduces the temperature locally. That effect may be felt in the degree of humidity of the air, the amount of precipitation, the degree of evaporation, and in the feeding of springs and rivers.

a. Humidity of the Air.

The observations so far available show that forests do not affect the *absolute* humidity of the air to any appreciable extent. Those made in Bavaria yielded the following results:—

Season	Mean Absolute Vapour Tension, in Inches.		
	In the Open, 5 feet above Ground.	In Forest, 5 feet above Ground.	Excess in Forest.
Spring . .	·2788	·2824	+ ·0036
Summer . . .	·4626	·4618	− ·0008
Autumn . . .	·2806	·2886	+ ·0080
Winter . .	·1820	·1918	+ ·0098
Mean of Year . .	·3010	·3064	+ ·0054

These figures show that the increase in forest did not reach 2 per cent. of the quantity outside. More extended observations have since shown that the difference is even smaller, and in some cases forest air has been found to contain less absolute vapour tension than open air.

It is different with the *relative* humidity of the air. As the temperature of forest air is on the whole lower than that of open air, while the absolute humidity remains the same, it follows that the relative humidity of forest air should be greater than that of open air, more especially in summer. The following data will illustrate this:

The Bavarian observations of 1868—69 gave the subjoined results, as a general average:—

Season.	Mean Relative Humidity, in per cent. of Saturation.		
	In the Open, 5 feet above Ground.	In Forest, 5 feet above Ground.	Excess in Forest.
Spring . . .	74·96	80·66	+5·70
Summer . . .	71·92	81·20	+9·28
Autumn . . .	82·72	87·94	+5·22
Winter . . .	84·19	89·43	+5·24
Mean of Year . .	78·45	84·81	+6·36

These observations showed that the mean annual excess amounted to 6·36 per cent. There was, however, a decided difference according to the altitude of the stations. While the excess amounted to only 3·14 per cent. at 1,066 feet above the sea, it was as much as 8·79 per cent. at 2,956 feet elevation. Further differences have been recorded according to the species, as the following data will show, representing the averages of the German and Swiss observations:—

Season.	Excess of Relative Humidity in Forest over the Open Country, in per cent. of Saturation.			
	Beech.	Spruce.	Scotch Pine.	Larch.
Spring . . .	+1·91	+6·92	+2·93	+2·83
Summer . . .	+9·35	+8·56	+3·87	+7·85
Autumn . . .	+4·07	+7·01	+4·24	+5·45
Winter . . .	+1·73	+4·76	+2·70	+ ·34
Mean of Year . .	+4·27	+6·81	+3·42	+4·12

Evergreen dense spruce woods produced a much greater effect than the thin crowned Scotch pine, or the deciduous beech and larch. At the same time the greatest effect was recorded in beech woods during summer, due to the dense leaf canopy which exists in such woods at that season.

The detailed figures show, that the mean annual excess in forests ranged from 3 to 10 per cent., which explains

why dry air currents striking through forests become in a short time relatively moist, so that precipitations may be caused. At any rate there can be no doubt that the formation of dew is much greater in the vicinity of forests than on open ground away from woodlands.

The latest observations, especially those made in Baden by Schuberg, have thrown considerable doubt on the conclusions drawn from the earlier observations. According to Schuberg, the difference is much smaller than that indicated by the above-mentioned data.

b. Precipitations, or Rainfall.

The question whether, and in how far, forests affect the rainfall, is one which has been actively discussed for many years past, but so far no final decision has been possible. That forests can affect precipitations follows from the facts, that forest air is relatively moister than air in the open, and that the trees mechanically affect the movement of the air; but, on the other hand, the rainfall depends chiefly on other much more powerful agencies, in comparison with which the effect of forests is small. Numerous comparative observations have been made, but only a certain portion has so far been published, and unfortunately those which seem to indicate a decided effect of forests on the rainfall are not always very reliable. The great difficulty in comparing the results of observations at forest stations (that is to say stations situated inside a forest) with those of the ordinary meteorological stations, consists in the fact, that elevation above the sea affects the rainfall most powerfully, because air cools on rising and precipitations become more frequent with elevation.

Although further observations are necessary, before a final conclusion can be arrived at, the following data may prove interesting:—

In the Prussian system the forest stations have shown the subjoined increase of rainfall over the average rainfall of the open country as taken from the ordinary meteorological stations:—

	Excess of Rainfall in Forest Stations over that of Open Country, in per cent. of the latter Rainfall.
Between Sea level and 328 feet elevation.	1·25 per cent.
„ 328 and 556 feet „	14·2 „
„ 1,969 and 2,297 feet „	19 „
„ 2,297 and 2,625 feet „	43 „

These figures seem to indicate that in the plains, forests have very little effect upon the rainfall, if any at all, but that their influence becomes considerable with increasing elevation in mountainous countries.

The results of 7 years' observations made at two stations near Nancy show a decided increase of rainfall in the forest. The stations are situated 1,247 feet above the sea, one in the middle of an extensive forest 5 miles to the west of Nancy, the other in an almost woodless country 6 miles to the north-east of Nancy. The results were as follows:—

	Increase of Rainfall in Forest over that in the Open, in per cent. of the latter.
February to April	7 per cent.
May to July	13 „
August to October	23 „
November to January	21 „
Mean of Year	16 „

that is to say, an increase of 16 per cent. at the forest station.

Other evidence tending in the same direction is available, but the Bavarian observations, as well as those made during the last few years, do not justify any direct conclusion as to any increase in the absolute rainfall due to the action of forests. The increased quantity of precipitation, which has been recorded in some cases, may to a considerable extent be accounted for by an increased formation of dew, which is registered together with the rainfall.

On the whole it may be said, that various physical factors act towards rendering forests excellent condensers of vapour, because they have a lower temperature, a moister air, and break the force of air currents. These properties are more evident in elevated positions than in low lands and in the vicinity of the sea, where they are swamped by other more powerful agencies. Absolute certainty in respect of these phenomena can only be obtained through further extensive observations.

The presence of a forest crop prevents a portion of the rainfall from reaching the ground, because it is intercepted by the crowns of the trees. The various measurements have yielded the following results:—

Stations.	Quantity of Rainfall which reached the Ground in well-stocked Woods, in per cent. of Total Rainfall.			
	Beech Woods.	Spruce Woods.	Scotch Pine Woods.	Larch Woods.
Prussian Stations .	76	·78	73	...
Bavarian Stations .	78	73	66	...
Swiss Stations . .	90	77	...	85

The total average of the Bavarian stations shows 77

per cent. of the rainfall as having reached the ground, whereas 23 per cent. were intercepted by the crowns of the trees, and which evaporated or partly ran down the trunks of the trees; the latter has been estimated as, perhaps, equal to one-half of the intercepted quantity.

Evaporation.

Owing to the lower temperature, the somewhat greater humidity of the air and the quieter state of the atmosphere, evaporation must be considerably smaller in forests than in the open. This has been conclusively proved by direct observations. Those made in Bavaria and Prussia show the following results:—

Stations.	Quantity of Water Evaporated from a free Surface of Water, Height in Inches.			Less in Forest expressed in per cent. of the total Quantity evaporated in the Open.
	In the Open.	In Forest.	Less in Forest.	
Bavarian . .	23·53	8·61	−14·92	−63
Prussian . .	13·16	5·98	− 7·18	−55
Mean . .	18·34	7·29	−11·05	−60

These data show that evaporation in the forest was only two-fifths of that in the open country.

The effect of this action is, that of the water which falls on the ground in a forest a considerably larger proportion is secured to the soil, than in the open. It has been estimated that about twice as much water penetrates into forest soil than into soil in the open country. That water is available to be absorbed by the roots, while any balance goes to the underground reservoirs, and helps to feed springs. Of considerable importance in this respect is the covering of forest soil.

Dr. Ebermayer's observations on this point, extending over 5 years, show the following results:—

	Parts.
Evaporation of water from soil in the open placed at	= 100
Evaporation from forest soil, without leaf-mould	= 47
" " " " with a full layer of leaf-mould	= 22

In other words, forest soil without leaf mould evaporated less than half the water evaporated in the open, while forest soil covered with a good layer of humus evaporated even less than one-fourth of that evaporated in the open.

The result of these peculiarities is, that forest soil retains, after allowing for evaporation, more water, than soil in the open, although some 23 per cent. of the rainfall is intercepted by the crowns of the trees, of which about one-half evaporates and is thus lost to the soil.

On the other hand, the roots of the trees take considerable quantities of water from the soil, especially at some distance from the surface; hence forest soil may be less moist in the root region than soil in the open, although it is moister near the surface. At the same time, open soil covered with grass and weeds, as it usually is when not cultivated, allows less water to penetrate into the soil than forest soil, while field crops take considerably more water from the soil than forest trees. The conclusion is therefore justified, and it is proved by every-day experience, that forests act most beneficially upon the preservation of moisture. Indeed, mountain forests, especially, have from time immemorial been looked upon as the preservers of moisture and the feeders of springs. At the same time, the presence or

absence of springs in a given locality depends chiefly on the geological formation. Sandstone and chalk formations are poor in springs, because the water sinks rapidly to a considerable depth, while the older formations are generally rich in them.

3. *Mechanical Effect of Forests.*

The mechanical effect of forests makes itself felt chiefly in regard to the distribution of the rain water, the preservation of the soil on sloping ground, the binding of shifting sand, the prevention of avalanches and the moderation of air currents.

a. Feeding of Springs and Rivers.

Most of the rainwater falling on a bare slope rushes down into the nearest watercourse in a comparatively short time, thus causing a rapid rise in the level of the stream. Only a comparatively small portion sinks into the ground, so as to become available for the feeding of springs. Of the rain falling over a forest, close on one-fourth is intercepted by the crowns of the trees, and the other three-fourths fall upon a layer of humus, which possesses a great capacity of absorbing water and of retaining it for a time. It has been shown, for instance, that mosses of the genus *Hypnum*, which grow under the shade of conifers, can absorb up to 5 times their own weight of water, and peat mosses of the genus *Sphagnum* up to 7 times; while the leaf-mould to be found in a middle aged well preserved beech wood can absorb and retain for a time a considerable quantity of water. Part of the water thus absorbed penetrates into the ground and becomes available for the feeding of

springs, while the rest gradually finds its way into the nearest stream. In this manner well preserved forests must have a decided effect upon the sustained feeding of springs and the moderation of sudden floods in rivers. When, however, the humus has been saturated with water, and rain continues, the effect of forests as regards inundations must cease, because the additional water follows the law of gravity and finds its way into the valleys. Hence the effects are of limited extent, a matter which has frequently been overlooked in discussing the subject. In order to moderate inundations to any appreciable extent, it would be necessary to keep a very large proportion of the catchment area under forest, and even such a measure would only afford protection to a limited extent.

b. Protection of the Soil.

Water rushing down a bare slope possesses a great mechanical power, by means of which it loosens the soil, and carries it down hill. In this way landslips are often caused, ravines are formed, and fertile land, situated at the foot of the ravines, may be covered with silt and rendered valueless. Frequently the *débris* collects in rivers and forms obstructions, which are followed by a diversion of the bed and erosion of fertile lands. The rate at which this process proceeds depends on the geological origin and the formation of the surface; the less binding the soil and the looser the formation, the greater the damage will be. If, on the other hand, such a slope is covered with a well preserved forest, the roots of the trees and the layers of humus keep together and

protect the soil against the action of water; besides, the crowns intercept and retain, at any rate for a time, a considerable portion of the water. On the whole, a series of obstacles are opposed to the movement of the water, which reduce its velocity and force, or at any rate divide it into numerous small channels. The beneficial effect of tree vegetation in this respect can be observed in most mountain ranges, and especially in the Alps from France to Austria. Wherever, in those parts, extensive deforestations have taken place, the consequence has been the gradual formation of a series of torrents, in all places where the surface did not consist of hard rock; the *débris* brought down has covered more and more fertile land at the base of the torrents, and this evil has grown to such an extent, that not only in France, but also in the other Alpine countries, great efforts have been made to re-afforest the denuded areas at a great outlay. When once the evil has been created, immediate afforestation is not possible; it must be preceded by the construction of dams, dykes, walls, &c., to steady the soil, until the young forest growth has had time to establish itself and once more lay hold of the surface soil.

The importance of maintaining a complete cover of vegetation in all such cases was recognized many years ago, so that already in the middle ages so called "Protection Forests" existed, which the then existing laws protected against devastation. Although the effect here described is perhaps most complete in the case of a well stocked forest, similar effects can be produced by covering the soil in other ways, as for instance by a dense growth of heather, by turf, &c.

Forests protect the soil not only in the hills, but also in low lands, wherever it consists of so-called moving or shifting sand, along the sea coast as well as in the interior of countries. The action in this case is due partly to their moderating the force of the air currents, and partly by keeping the soil together through their roots, by the formation of humus and the retention of moisture. In this way the Landes of France have, from a dreary waste, been converted into extensive forests intersected by cultivated fields.

c. Protection against Avalanches.

Although most avalanches in the higher hills originate above the upper limit of tree growth, there are many cases where the presence of a well preserved forest protects towns and villages lying below them by preventing the formation of avalanches, or by stopping their forward movement and increase as long as they are as yet small. Hence many forests in the Alps are maintained as a protection against avalanches.

d. Protection against Air Currents.

Forests break or moderate the force of air currents, and in this way afford protection to lands lying beyond them against cold or dry winds. Whether such effect is beneficial or otherwise, depends on the geographical position, the local climate, and the season of the year. Woodlands afford also shelter to cattle, game, and useful birds. Their importance in this respect should not be overlooked; forest grazing is frequently of greater

value than grazing on open ground; the presence of birds, which are the great enemies of injurious insects, depends often on that of woodlands.

4. *Hygienic Effect of Forests.*

Forests, in forming a substantial part of the vegetation of the earth, are an important agency for the production of oxygen obtained by the decomposition of carbon dioxide. Direct observations have also shown that forest air (like sea air) is much richer in ozone than the air of open countries, and especially of towns. Professor Ebermayer gives the following results, the maximum contents of ozone being indicated by 10, and complete absence by 0 :—

Stations.	Contents of Ozone in the Air.			
	Spring.	Summer.	Autumn.	Winter.
Average of the six Bavarian double stations situated inside and in the vicinity of forests	8·20	7·71	7·99	8·36
Aschaffenburg, town	6·81	6·24	5·35	6·04
Leipzig, town	5·42	6·93	3·65	3·37
Zwickau, town	3·23	3·11	2·21	1·81

The difference between forest countries and towns is greatest during winter, which seems to show that the presence of ozone does not depend on the action of the leaves. It was also found that the air inside forests, near the ground, contained slightly less ozone than along the edges of the woods, which may be due to the presence of large quantities of decaying matter (humus) in the forest.

As forests produce oxygen and ozone and protect

human habitations against injurious air currents, they have been held to exercise a beneficial effect upon the healthiness of adjoining lands. Instances are not wanting where forests are said to have given protection against the germs of malaria, but there are others, where they are said to have had the opposite effect. As far as India is concerned, in some cases the medical authorities of military cantonments ordered forests to be planted, and in others to be cut down. According to modern investigations ozone is believed to have no hygienic effect; more especially its presence or absence is said not to influence the development of epidemic diseases. If this is so, the salutary effect of forest air is probably due to the absence of dust, smoke and injurious gases, to the small number, or total absence, of microbes, and the greater tranquillity of the human mind.

5. *Æsthetic Effect of Forests.*

As forests increase the artistic beauty of a country, they must influence the character of the people, especially as they are favourite places of recreation. Many of the British woodlands were created, or are maintained, for their æsthetic effects.

CHAPTER III.

SUMMARY OF CONCLUSIONS.

THE various ways in which forests exercise an influence in the economy of man and of nature may be summarized as follows:—

(1.) Forests supply timber, fuel and other forest produce.

(2.) They offer a convenient opportunity for the investment of capital and for enterprise.

(3.) They produce a demand for labour in their management and working, as well as in a variety of industries which depend on forests for their raw material.

(4.) They reduce the temperature of the air and soil to a moderate extent, and render the climate more equable.

(5.) They increase the relative humidity of the air and tend to reduce evaporation.

(6.) They tend to increase the precipitation of moisture.

(7.) They help to regulate the water supply, produce a more sustained feeding of springs, tend to reduce violent floods, and render the flow of water in rivers more continuous.

(8.) They assist in preventing land slips, avalanches, the silting up of rivers and low lands, and arrest shifting sands.

(9.) They reduce the velocity of air currents, protect adjoining fields against cold or dry winds, and afford shelter to cattle, game, and useful birds.

(10.) They assist in the production of oxygen and of ozone.

(11.) They may under certain conditions improve the healthiness of a country.

(12.) Finally they increase the artistic beauty of a country.

Whether, and in how far, these effects are produced in a particular country depends on its special conditions. As regards the *direct* effects, enumerated under 1, 2 and 3, the following considerations are of importance in deciding whether existing woodlands should be preserved, or new forests created:—

(1.) The position of the country, its communications with other countries, and the control which it exercises over other countries.

(2.) The quantity and quality of substitutes for forest produce available in the country.

(3.) The value of land and labour, and the returns which land yields, if used for other purposes.

(4.) The density of population.

(5.) The amount of capital available for investment.

A country so situated that the importation of wood and other forest produce is comparatively easy and cheap (sea-bound, traversed by navigable rivers coming from countries which are rich in forests, or intersected by numerous railways and other means of communication), or which has control over other countries, as for instance colonies rich in forests, can dispense with extensive forests. In a country which is rich in coal, lignite, or peat, the production of firewood is of subordinate importance. Where iron or other substitutes for timber are available in sufficient quantity and at a low rate, forests are not required to the same extent, as in a country which does not enjoy such advantages.

Where land under field crops yields, even if forest produce is imported, a higher interest on the invested capital than under forest, the latter would, in this respect, be undesirable. If the population of a country is very dense, and all land is required for food, forests would be out of place. Where, on the other hand, waste lands exist, which are not required or unsuited for field crops, and where the population is at the same time in want of additional work, it may be advisable to create forests so as to increase the returns from surplus lands, and to provide occupation through the operations connected with the administration of the forests and the industries which the existence of forests tends to create.

In considering the advisability, or otherwise, of afforesting a country, with special reference to the *indirect* effects of forests, the most important points are its climate and configuration. The nearer to the equator, the more important becomes, as a rule, the forest question, and the further removed from it, the less important. While forests may in a hot country, with distinct wet and dry seasons, be absolutely necessary for the mitigation of extreme heat and dryness during certain parts of the year, and the regulation of the flow of water in springs and rivers, they may be injurious in a northern country, which is already too cold and damp. Similarly, a continental country may require forests, while a seabound country may be better without them, as far as climatic considerations are concerned. A mountainous country is much more in need of forests than a low lying country, on account of their beneficial action as regards landslips, avalanches, the carrying away of débris, the silting up of rivers and

low lands, sudden floods, and the sustained feeding of springs. As regards the protection against strong winds and shelter to cattle and useful birds, forests act beneficially in any country.

On the whole, no general rule can be laid down showing whether forests are required in a country, or what percentage of the area should be so used. The forest question must be determined on the special circumstances of each country. By way of illustration the areas at present under forest in a number of countries are shown in the following table:—

Countries.	Area under Forest, in Acres.	Percentage of Total Area of Country under Forest.	Forest Area per Head of Population, in Acres.	Distribution of Forest Area according to Ownership, in per cent. of total Forest Area.		
				State and Crown Forests.	Forests of Corporations, Endowments, etc.	Private Forests.
Servia	5,166,000	48	3·3	...	...	...
Russia, in Europe	527,427,000	42	6·1	60*	40	
Sweden	42,366,000	35	9·1	20	80	
Hungary	22,693,000	35	1·4	16	52	32
Austria Proper	24,161,000	33	1·1	7	18	75
Germany	34,350,000	26	·8	33	19	48
Norway	18,920,000	25	9·9	12	3	85
Turkey (including Bulgaria, Bosnia and Herzegovina)	20,512,000	22	3·5	...	...	...
Roumania	4,883,000	22	·9	...	...	...
Italy	14,235,000	22†	·5	4	43	53
Switzerland	1,930,000	19	·7	4	67	29
France	20,750,000	16	·6	11	23	66
Greece	2,026,000	16	1·2	80	...	20
Belgium	502,000	7	·1	...	...	...
Holland	554,000	7	·1	...	...	...
Spain	7,742,000	6	·4	82‡	...	18
Portugal	1,166,000	5	·2	...	...	...
Denmark	477,000	4	·1	...	...	...
Great Britain and Ireland	2,790,000	4	·1	...	...	...
Total for Europe	752,650,000	30	2·5	...	...	...
United States of N. America	380,000,000	17	7·6	...	...	...
East India, British	140,000,000	25	·5	50*	50*	

* Approximate. † Includes olive woods.
‡ Includes probably the Corporation forests.

Considerable differences exist in respect of the data available for several of the countries. In all such cases the data which appeared most reliable, have been entered in the above table. The percentage of forest area varies from 48 to 4 per cent., and the area per head of population from 9·9 to ·1 acres. This shows that the general conditions in the various countries must make different demands in respect of afforestation. Servia, Russia, Sweden, and Norway, may as yet have more forest than they require for their own population. On the other hand, Great Britain and Ireland, Denmark, Portugal, Holland, Belgium, and even France and Italy have a smaller forest area than is necessary to supply them with a sufficient quantity of forest produce. At the same time, they are all seabound countries, and consequently subject to conditions, which differ altogether from those found in continental countries; most of them are under the influence of moist sea winds, and all are favourably situated in respect of importation by sea.

Intimately connected with the area under forest in a country, is the state of ownerships. Forest owners may be grouped into the following three great classes:—

(*a.*) The State or the Crown.
(*b.*) Corporations, Endowments, etc.
(*c.*) Private persons.

Where, apart from the financial aspect and the supply of work, forests are not required on account of their indirect effects, and where importation from other countries is easy and assured, the Government of a country need not, as a rule, trouble itself to maintain or acquire forests. But where the opposite conditions exist,

that is to say, where forests are necessary to produce climatic and mechanical effects, and where the cost of transport over long distances becomes prohibitive, a wise administration will take measures to assure the maintenance of a certain proportion of the country under forest. This can be done, either by maintaining or constituting a certain area of State forests, or by exercising a certain amount of control over corporation and private forests. How this question should be treated will be explained in the next part of this volume.

PART II

THE STATE IN RELATION TO FORESTRY.

INTRODUCTION.

As indicated in the first part of this volume, forestry has for its primary objects the production of forest produce, and the realization of certain other effects. Hence, forestry is an industry based upon the productive power of the soil, which satisfies certain requirements of the inhabitants of the earth. This industry differs from others, and especially from the production of field crops, chiefly through the long time which is required for the maturing of the produce. While that process takes in other industries only a comparatively short time, forest trees may require one hundred and more years before they reach the size necessary for a particular purpose. Under these circumstances, continuity of action, extending over a long period of time, is an essential condition for successful forestry.

The industry also requires considerable areas, whenever a steady annual income is expected, because there must be woods of various ages, and each wood must be of a certain size. Competent managers, moreover, are expensive, and in order to utilize them fully, they must administer a considerable area. The construction of means of transport, such as roads, tramways, forest-railways and other works of this class, pays only if considerable quantities of produce are moved over them. These and other considerations make it clear, that successful forestry conducted on economic principles is,

as a rule, only possible on large properties, such as may be held by the State, communes, other corporations and wealthy private persons. Only in these cases is the management fairly independent of personal or temporary fancies of the owner.

The task of the industry is to do justice to true economic principles, in other words, to increase steadily, and to highest practicable pitch, the productiveness of all natural forces and of the capital invested in the business. In some cases the object of management centres in a high return; in others different objects are aimed at. In the latter case the sacrifice made from a financial point of view should be duly compensated for by other results.

The scientific treatment of the economic position which forests occupy in the State and in Political Economy is called Forest Policy. It deals with the social aspect of forestry, and it considers specially the duties which the State has to fulfil as regards forests, so that they may, in the highest possible degree, answer the demands, which are made on them in the interests of the community as a whole.

These duties will be shortly indicated in the following pages; they vary according to the objects for which forests are maintained, and the proprietorship. Accordingly, the subject may be dealt with under the following headings:—

Chapter I. Duties of the State in regard to Forestry.
,, II. Protection Forests.
,, III. State Forests.
,, IV. Forests of Communes, Corporations, etc.
,, V. Supervision of Private Forests by the State.

In dealing with this subject the works which have been principally utilized are:—

(1.) Forest Policy, by Dr. I. Lehr, in Lorey's Handbuch der Forstwissenschaft.

(2.) Forest Policy, by Dr. A. Schwappach, in Frankenstein's Handbuch der Staatswissenschaften, and,

(3.) Forest Law, by B. H. Baden-Powell, C.I.E., Hon. M.A. Oxon. London: Bradbury, Agnew, & Co. Ld., 1893.

CHAPTER I.

DUTIES OF THE STATE IN REGARD TO FORESTRY.

TRUE human happiness can be secured only by social intercourse. The latter, however, imposes restrictions on the individual; it demands institutions of such a nature that, on the one hand, sufficient latitude is afforded for personal development, activity, and individual deeds, and, on the other hand, that one individual may not disturb or destroy the sphere of action of his neighbour. This object can be realized only by institutions, which have for their object the furtherance of the common interests, in subordinating the interests of the single individual to the joint interest of the whole community, whenever the two clash.

The logical consequence of such an arrangement is, that all men should have an equal chance of personal development, and that all individuals should equally share the fruits of such institutions. This, however, is not in accordance with what actually took place in former times, and is still taking place in the world. History shows that might has always been an important factor in all social arrangements; certain classes of society have always striven to appropriate for themselves more than their share of social production, and to subordinate other classes to their own will. Frequently such subordination has been sanctioned by laws. For laws are often made by the more powerful classes.

With the development of culture and the consequent

creation of new conditions, the formerly subordinated classes gradually asserted their rights, and participated more fully in social life, until their demand for equality had to be admitted. They were thus created free citizens in all civilized States, possessing equality before the law, and to a certain extent equal political rights; in the latter respect some differences still exist, due to position and property.

The forces by which public order is maintained, are (1) education, moral sense, and custom, which assert themselves in an unobtrusive manner, and (2) social associations, which are partly voluntary, that is to say, it is free to any one to join or not, and partly compulsory. Of the latter the most important is the State, which represents all inhabitants who live within its limits.

The State authorities exercise the supreme power within the limits of the State territory, to which all persons and goods are subjected; they make laws which are binding on all alike. The State is a social necessity for mankind.

The State has various duties to perform. In the first place it must make laws with the object of securing their rights to all citizens, and of protecting them against illegal interference of any kind; it must also maintain such laws. The Government of the State rests sometimes with the ruler only; in other cases the representatives of the people exercise the supreme power; and between these extreme cases many intermediate forms are found. By the general laws of a country limits are drawn within which full liberty is given for individual development, and through it for the advancement of the welfare of the whole community.

The action of the State must frequently also aim at directly furthering the welfare of the peoples, by removing obstacles which obstruct the development of the individual, or by creating institutions which strengthen his working power. In this respect State action is called for, where the power of the individual is not sufficient to attain objects which are essential for social development; where the advantages to be derived are not sufficient to induce iudividuals to take up the task; where free action on the part of the individual endangers the interests of the community as a whole, or where it is preferable that the State should guard the interests of the community. The last occurs when permanent institutions must be made independent of momentary personal fancies or wishes; in such cases the State alone affords sufficient guaranty for continuity of action in a given direction.

From the above remarks it will be seen that there are certain matters of general interest which are better kept under the care and management of the State, while others may be left to the free activity of the individual. The limits between the two classes are by no means easy to draw, nor can they be fixed once and for ever; they depend on the degree of civilization and education, and the character of the peoples, as well as on the industrial condition of the country.

Applying now what has been said above to the case of forestry, it follows that the State must interfere, sometimes limiting and sometimes furthering, whenever the welfare of the community as a whole demand it; beyond that it should not go. The nature and extent of the measures which the State should take in this respect depend on—

(1.) The special requirements of the country, as determined by the general culture of the peoples, and the situation and nature of the country.

(2.) The nature of the proprietorship of the forests.

As long as the forests are not of national importance, or are in the hands of proprietors, who offer a sufficient guarantee for a suitable management, interference by the State is not called for. On the other hand, it becomes as a rule necessary in cases like the following :—

(1.) Where the interests of the community demand the maintenance and suitable treatment of forests which belong to a large number of small proprietors.

(2.) Where the existing legal conditions (servitudes, joint property, etc.) produce conflicting interests.

(3.) Where the existing means of communication are not sufficient to carry the necessary forest produce to special localities.

(4.) Where forests are necessary on account of their indirect effects.

Accordingly, matters differ in the various civilized States of the earth. In some no State control whatever is exercised over forest property, in others it is restricted to protection forests and to State forests, in others it extends to communal forests, and in others again also to private forests.

The control of the State over forests, whatever the proprietorship may be, must be regulated by laws. In some cases such laws are incorporated with the general laws of the country, in others special forest laws have been passed. In either case, such laws must provide for the following matters :—

(1.) Determination of the areas which shall be con-

sidered forest, and are as such subjected to the forest laws, a distinction being made between:—

(*a.*) Protection forests, to be described in the next chapter.

(*b.*) State forests.

(*c.*) Forests belonging to corporations, communes, villages, etc.

(*d.*) Private forests.

(2.) Determination, regulation, and commutation of forest rights, and prevention of the creation of new rights.

(3.) Protection of the forests against unlawful acts, such as theft or damage; prevention of such offences; and punishment of forest offences.

(4.) Protection of forest produce in transit.

(5.) Constitution of a staff of forest officers, provision to invest them with suitable legal powers, and determination of their duties and liabilities.

The details of these matters cannot be dealt with in this place, and the reader is, therefore, referred to law books on the subject; more especially to Baden-Powell's "Forest Law." The following chapters will indicate whether, and in how far, State interference is called for under the different forms of proprietorship, and in the case of protection forests. As the latter are ordinarily most in need of interference on the part of the State, they will be taken first.

CHAPTER II.

PROTECTION FORESTS.

By protection forests, in the present sense, are understood forests which must be maintained as such on account of their influence upon the welfare of the community as a whole, more especially for the protection against natural phenomena and the preservation of the climate. Such forests may be the property of the State, communes, or private persons.

The law of the country should provide for the formation of protection forests, if they are required for one of the following purposes :—

(1.) Preservation of the soil, especially on hill sides and where shifting sands occur, so as to prevent erosion, denudation, landslips, the formation of ravines, the silting up of fertile lands at the foot of hills and of river beds, or the extension of shifting sands near the sea shore as well as inland.

(2.) Preservation and regulation of the water supply in springs and rivers, so as to secure an even flow and prevent floods, or, where the water is required for irrigation, to reduce evaporation in the catchment areas.

(3.) Protection against injurious air currents, such as gales, cold, or hot winds.

(4.) For the benefit of the public health.

(5.) For the prevention of avalanches.

(6.) For the defence of the country.

Protection forests may be subjected to special regulations in respect of:—

(*a.*) the manner of cutting and working generally;

(*b.*) the execution of planting or sowing;

(*c.*) the construction of accessory works, such as dams, weirs, erection of hurdles, fixation of shifting sands, etc.;

(*d.*) the regulation or prohibition of cattle grazing, removal of litter and similar matter.

The procedure followed in declaring protection forests differs considerably in the various civilized States; in some the proprietor may demand that his forest be declared a protection forest; in others an official selection of protection forests has been made; in others again protection forests are declared from time to time, as necessity arises.

Before the State is justified in interfering or proceeding to the declaration of protection forests, and thus imposing restrictions in their management, certain conditions must be fulfilled, such as the following:—

(*a.*) The object, to be realized by the restrictions, must be of public importance.

(*b.*) The advantages to be derived from the restriction must be greater than the disadvantages caused thereby.

(*c.*) The object must be actually realized, without another cheaper way being available.

(*d.*) Compulsion should only be resorted to, if private efforts are unable to realize the object in view.

(*e.*) Compulsion must not go beyond what is actually unavoidable. It is always desirable to let it be preceded by an effort at a friendly settlement of the

difficulty. In cases of urgent danger, however, prompt action must be taken.

(*f.*) Owners, who are subjected to loss or interference of rights, should be compensated. Such compensation is not necessary in cases where damage is to be prevented for which, if it occurs, the owner would be responsible. Considerable difficulty is frequently experienced in deciding who shall pay the compensation, or how it is to be distributed amongst those who are liable to bear it. (Protection against wind, shifting sand, preservation of moisture, etc.)

The measures to be taken against threatening dangers differ very much. In some countries it is considered sufficient to maintain existing forests; the authorities are satisfied with insisting on the areas remaining forest, and their not being devastated. In other countries, afforestation of bare lands can be enforced.

In order to prevent too great a division of property, that of protection forests should be subject to State sanction. If the proprietorship is already much divided, it is advisable to constitute an association, and if necessary this should be compulsory.

The State should have authority to undertake the management of protection forests, if the object in view cannot be realized in any other way.

If restrictions prove insufficient, or too cumbersome, expropriation may be considered. It has the advantage, that it insures the realization of the object in view, renders awkward compulsory restrictions unnecessary, leads to a reduction of the cost of supervision, and simplifies the question of compensation.

Expropriation must be provided for by law. Objects of expropriation are property and rights over property which obstruct public objects.

The cases, in which expropriations are admissible, should be fully detailed in the law. The decision, whether the law is to be put into operation, should ultimately rest with the law courts, though this is by no means the case in all countries.

If the area to be expropriated forms only part of a property, it may be necessary to take up the whole; when for instance what remains over cannot be economically utilized.

The compensation should be equal to the value of the property, or the right, as the case may be; in other words, it should at least be equal to the amount which can be obtained by private sale in the open market; in some cases a certain percentage over and above such value is paid. The compensation consists generally of money. If both parties agree, other property, such as forests, or fields may be given in exchange for the area expropriated.

CHAPTER III.

STATE FORESTS.

THERE exists hardly a country, in which the State, or the Crown, does not own forests. As a rule such forests were originally at the disposal of the ruler of the country, but by degrees they became, in most cases, State property. The present chapter deals with the latter class of forests, which in many countries form an important part of the national property. A reference to page 54 will show that in some European countries up to 80 per cent. of the total forest area belongs to the State, whereas only in a few cases the State owns no such property. For India, it has been estimated that at least half the total forest area belongs to the State.

As the State appears in a double capacity in this respect, namely, as the power which lays down the general forest policy of the country, and as the proprietor of part of the forest area, the question may naturally be asked, whether it is desirable that State forests should be maintained, or whether it is preferable that such forests should be held by private persons. Reasons have been advanced for and against the maintenance of State forests, the more important of which must be shortly indicated.

1. *Reasons for Maintaining State Forests.*

These may be arranged as follows:—

(a.) *Reasons based upon certain peculiarities of the*

forest industry, which enable the State, in preference to private persons, to maintain a suitable management of the forests.—The view has frequently been expressed that in forestry private interests do not coincide with those of the community as a whole. The former centre in the realization of the greatest profit, which may demand the production of only small material, or even the actual devastation of the forest whenever the capital represented by the growing stock and the soil can be more profitably utilized in other ways.

The State, on the other hand, is more interested in the realization of a sustained yield, so as to provide for the requirements of the nation, especially as regards timber of large size. The latter, it is said, leads generally to unfavourable financial results. This is, no doubt, true in many cases, but not in all, or for ever; the price of large sized timber, required for special purposes, may rise sufficiently to make their production financially remunerative.

In State forestry, it is said, the interests of the proprietor and of the community as a whole are brought into harmony, even if the management yields only a low rate of interest on the capital value of the forests. The State is assumed to last for ever, and the outlay on formation, regeneration and tending of the forests will be re-imbursed, even if after a considerable space of time. Moreover the State should not look merely at financial success, because it has also an interest in the production of a sufficient quantity of produce, and in obtaining it from the smallest possible area, so that the remaining, and better, part of the land may be available for other purposes; any financial loss caused thereby, it is argued,

is merely apparent, since the outlay goes to the people in the shape of wages, and the apparent loss is more than made good by the flourishing of industries, which produce a high taxing capacity of the people. These arguments are, however, unsound; industries, to be in a healthy condition, must be conducted on financial principles; though temporary help may be wanted for young industries, when once started they must stand or fall on their own merits.

A further argument under this head is, that forestry can only be profitable if conducted on large areas; hence it requires a large capital, which is only in exceptional cases at the disposal of private parties. This argument holds good in many cases, but by no means in all.

Finally, it is said, that forestry is a comparatively simple business, that it requires little labour, while the control is easy, and that it offers little or no opportunity for speculation; hence it is specially adapted for State enterprise, and less so for a private industry.

(b.) *Reasons of State Finance.*—State forests are considered to be a suitable source of public revenue; the income is steady, sustained and safe. At the same time it is an income, the payment of which is not felt by the people.

State forests also form a reserve capital which can be made available in times of special need, either by pledging the property against loans, or by extra cuttings. As far as the last point is concerned, it must not be overlooked, that in times of need prices generally rule low, so that extra cuttings would not be indicated.

(c.) *Social Political Considerations.*—The possession of State domains increases the prestige of the State.

Again, the maintenance of State domains prevents the accumulation of too much landed property in a few private hands.

Thirdly, if a certain proportion of the forest area is the property of the State, all supervision and control of private forests can be abolished.

(d.) *The State, by owning and managing a certain area of forests, can do justice to various tasks and objects which do not directly result in income.*—This argument refers to protection forests, the supply of forest produce of a certain description and quantity, supply of work in poor districts and similar matters. As regards the latter point, it must be noted, that labour will be required, whether the forests belong to the State or to private parties, though there may be some difference in the quantity.

2. *Reasons against Maintaining State Forests.*

These may be arranged under the following four heads :—

(a.) *Danger of a mischievous one-sided utilization of State forests on the part of Government.*—Owing to the receipts from State domains, the Government is to some extent, or for a time, independent of the parliamentary power to sanction taxes. Or, the Government may grant privileges to members of the party which supports it, and withhold them from its opponents. These arguments have, however, little or no weight now-a-days.

(b.) *The possession of State domains may lead to a conflict of duties on the part of Government.*—It is below the dignity of the State, if the Government and private

persons compete in the open market, or contend in the law courts.

(c.) *State domains are considered injurious*, because they interfere with the natural development of national industries and reduce the opportunity for paying enterprise on the part of private persons.

(d.) *State forestry is said to be financially undesirable*, because the State cannot manage forests so profitably as private persons. This refers less to the technical management than to the preparation and disposal of the produce. As regards the latter, the objection carries, no doubt, much weight.

3. *Conclusions.*

The above remarks justify the conclusion that, on the one hand, State proprietorship need not be extended to all forests, and on the other, there is no reason why the State should, as a matter of principle, dispose of its forests. This holds good as long as State forests are either protection forests, or yield an adequate income. If neither is the case, then conversion or sale may be indicated.

Purchase of forests by the State may be recommended, when they are required as protection forests, when already existing Government estates require to be consolidated, or where additional work is wanted in congested districts.

4. *General Principles according to which State Forests should be Managed.*

State forests should afford the greatest possible advantage to the community as a whole, and the system of management should be shaped accordingly.

The question, in what manner the community derives the greatest possible advantage from its forests, has given rise to prolonged discussions, which have by no means terminated. The advantages may be represented by direct and indirect benefits; the former, again, may be represented by cash, quantity of produce, or produce of a certain kind, or generally by the financial results of the industry. All these considerations generally express themselves by the manner of determining the rotation under which State forests should be managed.

There is one party which demands that State forests should be managed according to principles differing from those applicable to private forests; while the financial principle is admitted in the case of private forests, such advocates maintain that other considerations should determine the management of State forests, such as the production of the greatest volume, and the most suitable quality of produce, or the highest possible yield, irrespective of interest on the invested capital.

Another party will admit no difference between private and State forests; it maintains that State forests represent capital, which should yield to the nation as a whole the highest possible interest.

In the author's opinion, there should be, in principle, no difference in the management of private, communal or State forests, but without going so far as the so-called purely finance party. There is a way of expressing the true forest policy in such a manner, that it is applicable to all forests, whether they belong to private persons, communes, or the State. True forest policy says:—As forests represent capital, their management should, in

the first place, be determined by financial considerations, but the management thus indicated should be modified in so far as other considerations may demand.

It rests with the proprietor of the forest to decide what other considerations shall be taken into account, over and above those laid down by the general laws of the country. In this respect the agricultural classes deserve special consideration, but it is a mistake if the State is to be guided by pseudo-philanthropy. State forests belong to the nation as a whole; by giving excessive privileges to a part of the people, the rest of the nation is deprived of its legitimate rights. This fundamental principle has frequently been overlooked, or set aside.

CHAPTER IV.

FORESTS OF COMMUNES, CORPORATIONS, ETC.

In its widest sense a commune means any association which has or holds something in common. In its narrower sense, as here used, by commune is understood a group of persons enjoying the right of a juristical person, especially as regards more public matters. Communes may hold joint property and they exercise political functions, levy local taxes, entertain their own police, etc. Forests frequently form an important part of the communal property.

Communal forests have been originated in many ways, such as purchase, gift, planting of communal lands, or even through prescription. The Indian forest law provides for the allotment of Government lands to communes, to form village forests.

The returns from such forests benefit the members of the commune either indirectly, or directly; the former, if the receipts from the forests go to the communal exchequer and are used to defray the general expenses of the commune; the latter, if the yield goes directly, either in material or cash, to the members of the commune. In the second case the right of utilization may be attached to the personal membership, or the possession of land, or a house.

In many countries the communal forests amount to a considerable portion of the total forest area (in Switzer-

land 67%, Hungary 52%, Italy 43%, France 23%, Germany 19%, Austria 18%).

Although communes should have a large measure of liberty in managing their own affairs, as regards their forest property a certain amount of supervision on the part of the State is indispensable for the following reasons:—

(*a.*) The personal interests of the members of the commune for the time being are likely to injure the sustained yield of the forests; more especially the poorer members constantly urge more extended utilization than the forests can stand.

(*b.*) Communes, which are in debt, are inclined to meet their liabilities by over working the forests.

(*c.*) The forests of a commune are not always of sufficient extent to secure a competent manager for them at a reasonable outlay.

(*d.*) The maintenance of communal forests tends to consolidate and strengthen communal life.

(*e.*) It is of importance to the State as a whole, that communal forests should be maintained, owing to their general importance.

The manner and extent of State control over communal forests is not in all cases the same. They depend on the constitution of the commune and the degree of political education. Hence, in the case of large towns, supervision is generally less necessary, than in the case of rural communities.

It is of importance that supervision should not go beyond what is really required. It is a mistake to demand more, than that the forests are managed economically and that their yield capacity is not

reduced. As a matter of fact State supervision differs considerably in various countries. The following are the principal forms of supervision.

1. *General Supervision of the Forests.*

The object of this is to maintain the general productiveness of the communal property; it comprises prohibition of devastation, control over the sale of forests, their conversion into fields or meadows, and compulsory re-afforestation. Beyond that, supervision should not be extended.

2. *Technical Supervision of Management.*

This is generally arranged so, that the working plans, deviations from them, conversion into fields, sales and extraordinary cuttings require previous sanction by the State authorities, while the administration is otherwise left to the communal authorities.

In some cases, State officials actually prepare the working plans; in others, the communal officials do so and then submit them for sanction. As a general rule these working plans are prepared on the principle of a sustained yield; this secured, the requirements and wishes of the commune should be fully considered. Anticipations of cuttings, though undesirable on general grounds, may be sanctioned, provided they are compensated for by subsequent savings.

In some countries communes may secure proper protection and administration in their own way by engaging the services of competent officials. In others the State reserves to itself the right of approving or rejecting the proposed officials, or of examining them

before approval; or such persons must pass the examinations laid down for Government forest officers.

3. *Management through Government Officers.*

In various countries the communal forests are managed by government officers in the same, or a somewhat modified, way as State forests.

The system has the following advantages:—

(*a.*) The objects aimed at can be fully realized.

(*b.*) The management is likely to be better and frequently also cheaper.

Where the forests of a commune are not large enough to occupy a fully competent manager, they are managed together with those of neighbouring communes, or with State forests, so as to form one executive charge.

This method of management has yielded excellent results. It is not in accordance with the principle of self-government on the part of communes, and it may, in some cases, cause a too minute management of communal forests, where a more simple method of management would suffice. At the same time, in all such cases, the communal authorities are expected to co-operate, to express their wishes, and to appeal against technical decisions which appear to them objectionable.

In many cases only the technical management is exercised by the State officials, while supervision, protection, and the execution of the several works is left to the commune. The actual work can frequently be done cheaper by the commune than through State officials.

Where communal forests form part of a mixed charge,

the commune contributes towards the pay of the officer in charge, such contribution being generally calculated by area.

The sale or other disposal of the yield is best left to the commune.

4. *Other Matters.*

The sale, purchase, and partition of communal forests are generally subject to sanction by the State.

Forced afforestation is now-a-days admissible only in the case of protection forests.

Forests belonging to endowment funds, universities, monasteries, etc., are in some countries treated in the same way as communal forests, in others, as private forests.

CHAPTER V.

SUPERVISION OF PRIVATE FORESTS BY THE STATE.

1. *Reasons for State Supervision.*

It has been alleged that amongst the general tasks of the State is comprised the duty of seeing that articles necessary for the welfare of the people are forthcoming, and that they are suitably distributed over the country. In the case of forestry such articles must be produced without occupying more land than is necessary, unless indeed the absolute forest soil is more than is required for the purpose. Wood, it is said, is an important article of consumption, which is absolutely necessary.

It is further maintained that measures taken in the above direction for the public welfare do not constitute an illegal interference with private interests, because forests have always been subject to restrictions, so that present owners obtained them burdened with the right of interference.

Thirdly, it is said, that by such interference the owner is not deprived of anything to which he is entitled, since the object of interference is to secure the best possible utilization of the forests, and to check abuse of the property.

Hence, it is said, State supervision is necessary and desirable because:—

(*a.*) The economic means of private persons are not sufficient for regular forest management. It is said that private persons rarely have the necessary knowledge to introduce and conduct a systematic management; their properties are frequently too small to secure the services of competent managers; frequently they do not possess the necessary funds; hence private forestry, if uncontrolled, leads to devastation.

Supervision, it is further said, is necessary, because private persons cannot estimate the total requirements of the country, nor arrange the management of the forests accordingly; to do this requires joint action, and not action distorted by the personal interests of each individual.

(*b.*) Special stress is laid upon the point, that private motives are opposed to the true aims and objects of forestry. It is said that the returns of forestry occur so late that he who sows does not reap; hence private owners are inclined to favour their own momentary interests to the disadvantage of future generations. They will frequently meet pecuniary demands by converting growing stock into money. The consequence might be overstocking of the market at one time, and a wood famine at another.

(*c.*) Without State supervision, the rights of third persons over private forests might be interfered with.

2. *Reasons against State Supervision.*

The reasons brought forward against State supervision of private forests, are somewhat on the following lines:—

(*a.*) Private forestry is fully sufficient to meet all

reasonable demands made on forests in the public interest. There is no reason to consider forestry as differing in this respect from other branches of industry; the best guaranty for a reasonable management is to be found in the prospect of a corresponding profit. Hence it is only necessary to remove all existing impediments, such as State forestry, and areas worth cultivating will be cultivated, and the system of management will be based on economic principles. Should an owner not be in the position of managing his forest properly, it would pass into other more competent hands. In short, the supply would be regulated by the demand, and prices determined accordingly. The fear of a wood famine is unnecessary, because it would not come suddenly, and the means of communication, substitutes for forest produce, and the possibility of reducing the use of it would meet an exceptional strain in this direction.

(*b.*) State supervision is not only unnecessary, but actually mischievous. The State has difficulty, if it is at all able, to decide always on the right measure of interference; it is very difficult to estimate the requirements. State forest officers are not always capable of determining the most suitable system of management, because the latter is not a fixture, but subject to changes from time to time. As a consequence, supervision is liable to be harsh and unjust. It destroys the desire on the part of private owners to take up forestry. It may lead to serious financial loss by insisting on the maintenance of too large an area of forest, thus actually stimulating extravagance in the use of forest produce.

State supervision, if efficient, is necessarily very

expensive. Otherwise the supervision exists only on paper.

(*c.*) Instead of obstructing private forestry in a one-sided manner, while fields are free from such interference, the State should try and stimulate it by removing all obstacles to it which now exist, by encouraging and facilitating the construction of means of communication, the establishment of forest schools, providing good laws for the protection of forest property, the commutation of forest rights, etc.

If, after that, private forestry does not attain the desired standard, the State should acquire so much forest, that no endangering of the common welfare is to be feared. Wherever a fair extent of State and communal forests already exists, private forestry may be released of all State interference.

3. *Manner of Supervising Private Forests.*

The measures provided in forest laws and regulations partly tend towards an increase in the quantity and quality of forestry produce, and partly to guard against extravagance in the consumption of such produce. They refer to :—

(*a.*) Prohibition to convert forests into fields or meadows, or to use them for other purposes.

(*b.*) Compulsory afforestion of certain lands.

(*c.*) Prohibition to devastate existing forests.

(*d.*) The laying down of fixed rules for the management of existing forests.

(*e.*) The taking under State management of private forests.

(*f.*) Insisting on proper forest protection.
(*g.*) Prohibition of dividing private forests.
(*h.*) Prohibition of selling private forests.
(*i.*) Regulation of the consumption of forest produce.

4. *Conclusions.*

The question, whether, or to what extent, the State should exercise a control over private forests from an economic point of view, cannot be answered straight off; the answer depends on the circumstances of each case. Under any circumstances the principle should hold good that the State should only interfere for weighty reasons in the interest of the common welfare. In that respect all depends on the proportion of forest already under State control, such as State and communal forests, and on the general condition of the country.

In England, the area of State forests is very small, and there are hardly any communal forests. And yet so far no State supervision over private forests has become necessary, owing to the favourable position of the country as regards imports of timber and substitutes for firewood.

In continental countries matters are somewhat different, because means of import are less favourable, and the quantity of substitutes, especially for firewood, smaller and less favourably distributed. Here the State might be called upon to interfere in the interests of the common welfare. The actual state of affairs differs very considerably. Taking Germany first, the distribution of forests amongst the three classes of proprietors, is as follows:—

State and Crown forests .	. = 32	per cent. of total forest area.	
Communal forests .	. . = 19	„	„
Private forests—			
Under control .	= 15		
Free . .	= 34	= 49	„ „
		100	

State and communal forests together amount to 51% of the total forest area, and these are all under State control.

Owing to this circumstance, supervision over private forests is hardly justified. As a matter of fact, nearly one-third of the private forests are under State control, bringing the area of controlled forests up to 66% of the total forest area, while 34% are free.

Private forests are practically free from control in

Prussia, Saxony, Meklenburg, Oldenburg, Anhalt, Altenburg, Schaumburg-Lippe, Gotha, Reuss, j. L.

In the other German States private forest are more or less subject to control.

Austria: under control.

Hungary: under control.

France: under control (more or less)

Switzerland: under control.

Italy: partly under control.

Sweden: partly under control.

Denmark: partly under control.

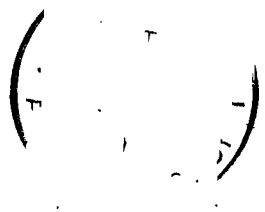
India: practically free.

Joint property, that is to say, property which belongs partly to private persons and partly to the State or communes, is generally under State control.

The above remarks do not, however, refer to protection forests, which have been dealt with in a previous chapter.

PART III.

FORESTRY IN BRITAIN AND IN INDIA.



INTRODUCTION.

It is proposed to apply the conclusions arrived at in parts I. and II. to the United Kingdom and to India, but before doing this, it will be useful to glance at the British Empire generally and to see how the forest question has been dealt with.

The British Empire extends from the north polar regions to about the 55th degree southern latitude. It consists of the mother country, of India, the dominion of Canada, the African colonies, Australasia and numerous other colonies in all parts of the world. The total area of the Empire and the population are estimated as follows:—

	Area in square miles.	Population.	Density of population per square mile.
United Kingdom	122,000	39,000,000	320
British India	1,560,000	287,000,000	184
The Colonies, about	7,113,000	19,000,000	3
Total	8,795,000	345,000,000	39

These figures do not include the lately acquired colonies in Africa.

In this vast Empire all sorts of conditions are met with. All shades of climate are represented, from eternal ice and snow to tropical heat; the rainfall ranges from absolute aridity to over 500 inches a year; exten-

sive low lands and plains alternate with mountain regions which attain to the greatest elevation on the face of the globe. Many parts of the area are densely populated, while extensive regions contain few inhabitants or none at all.

It is obviously impossible to deal with the forest question of such an Empire in a wholesale fashion; that question must be studied and answered for each country separately. In one respect, however, the Empire may be considered together, namely, as regards the timber requirements of the whole. The statistical records laid before Parliament show the imports and exports of timber to be approximately as follows:—

AVERAGE ANNUAL NET IMPORTS AND EXPORTS OF TIMBER INTO AND FROM THE SEVERAL PARTS OF THE BRITISH EMPIRE, CALCULATED FROM THE RETURNS FOR 1889 TO 1894.

Country.	Net Imports. Value in £.	Net Exports. Value in £.
Great Britain and Ireland	17,594,606	—
India	—	682,090
Ceylon	—	22,061
New South Wales	466,556	—
Victoria	831,162	—
South Australia	250,377	—
Western Australia	—	113,605
Tasmania	—	39,039
New Zealand	—	151,409
Queensland	—	10,933
Cape of Good Hope	160,113	—
Dominion of Canada	—	3,955,862
Jamaica	—	312,170
Barbados	64,751	—
Trinidad	41,341	—
British Guiana	40,532	—
Total	19,449,438	5,287,169
Net Imports into the British Empire...	14,162,269	—

This table, as will be seen, is not quite complete, because some of the smaller colonies have been omitted, as well as the lately acquired territories in Africa. In

some cases certain quantities of timber were included under railway materials, so that their value could not be ascertained. On the whole, however, the table shows clearly that the British Empire, although it is said to possess more extensive forests than any other nation, pays every year something like £14,000,000 to foreign countries for timber, besides about £1,375,000 paid for wood pulp.* Here, then, are broad facts which call for serious consideration. Endeavours to develop more systematic forest management in the Empire have frequently failed, because the limited funds required for such measures were not forthcoming, or other interests prevailed over the dictates of a sound forest policy, while the enormous sum of money which goes every year out of the Empire was lost sight of.

The above table shows further, that the mother country swamps all the colonies and India in respect of imports; of the timber valued at £17,600,000 required annually by the United Kingdom, its dependencies could furnish timber valued at only £3,500,000. And yet the United Kingdom has an enormous area of waste land amounting to some 14,000,000 acres, less than one-half of which could produce all the ordinary timber (valued at £18,000,000) which is now imported.† It has been said that these lands are required for other purposes such as grazing, or that they produce more income as shooting grounds, than if planted with timber trees, but there are good reasons in many instances to doubt such assertions. Be this, however, as it may, the same argument does not hold good in the case of most of the colonies, where enormous areas are available fit to produce many times the quantity of timber annually

* See p. 104. † See p. 105.

imported into the United Kingdom. And yet many of them are already themselves importing timber on a considerable scale. Take, for instance, Australasia: Of its area perhaps not more than one-third is at present put to profitable use, and the annual net imports of timber amount already to a value of £1,233,000. Surely, here is room for serious thought.

India has to provide an enormous population of 287,000,000 people with timber, firewood and other forest produce, and, apart from a certain amount of teak and fancy woods, it can probably do little towards an increased export of timber.

The Dominion of Canada has, during the years 1889–93, exported, on an average, timber valued at close on £4,000,000 annually. With proper measures of forest conservancy this quantity could not only be maintained, but enormously increased. But from many parts of the Dominion reports come of the rapid diminution of the area under useful timber, which leave no doubt that the exports must seriously decrease as time goes on. This is due to reckless cutting without consideration for the regeneration of the forests, and to forest fires. Indeed, the latter is the more formidable destructive agency of the two. A timber land explorer reported a few years ago that in one so-called "limit" in Manitoba 150,000,000 feet of white spruce timber had been killed by fire in the course of one season, that the fire not only killed the trees, but destroyed a good part of them and consumed the moss and vegetable deposits on the ground down to a depth of one foot. These matters are all the more important, because, within a limited space of time, the United States of

America are likely to require every stick which Canada can spare, thus reducing the imports to Britain by about 1,400,000 loads annually.

Turning now once more to Australasia, it may be confidently asserted that a systematic management of its forests is urgently required. It has already been stated that the annual imports of timber have risen to £1,233,000. At the same time only New South Wales has, it appears, extensive coalfields, which provide coal for that colony, and from which certain quantities are exported. Under these circumstances it may well be asked, how matters will stand some years hence, when the population has further increased. Not only the population, but the number of head of cattle, cultivation, railways, and telegraph lines, have increased during the last 20 years at the most marvellous rate. The population is nearly double what it was 20 years ago, and the same holds good as regards horses, horned cattle, and sheep; the land under cultivation has increased at the rate of about 150 per cent., and yet it represents only about one quarter per cent. of the total area. Although the increase may not go on as fast as in the immediate past, there are good reasons to believe that it will continue for many years to come, though at a somewhat reduced rate.

There can be no doubt that the demand for forest produce will considerably rise. The railways alone require nearly 2,000,000, sleepers annually; then timber is wanted in large quantities for building, fencing, mining operations, telegraph lines, and for a multitude of other purposes. Complaints have already been made that in many parts of the country the material for fencing is no

longer available, and this difficulty will increase with every succeeding year.

At the same time, the feeble efforts at forest conservancy so far made by the Australasian colonies fall far short of what is wanted, and the imports of timber must increase in the same proportion as the existing natural resources are exhausted, and as the population increases.

Next to India, the colony of the Cape of Good Hope has perhaps made the most vigorous effort to establish systematic forest management. And yet that colony imports a certain quantity of timber annually.

In how far the newly acquired territories in Africa may be able to come to the rescue of the mother country cannot yet be stated, but sanguine anticipations in this direction are likely to be disappointed. None of the other colonies are in a position to furnish the timber of daily use in Britain.

To sum up, it is clear to anyone, who approaches the subject with an unbiassed mind, that under existing circumstances the imports of timber into the Empire will increase rather than decrease as time goes on.

Then comes the important question whether, even if the Empire pays for it, foreign countries will be in a position to furnish the necessary timber for any length of time. Data, which throw light on this question, show that, although the several sources of supply may not dry up quite as quickly as some people believe, there are suspicious signs of a prospective falling-off in the supply. Under these circumstances, the British Empire as a whole should endeavour to safeguard against a calamity which, if it has once set in, can only be remedied after a considerable lapse of time. Although some of the

dependencies have made great progress in this direction, others are as yet in the very beginning, and many of the colonies are still "playing" with the forest question. The reason for this is to be found in the constitutional aversion of the Briton to State interference in the case of anything which partakes of the nature of an industry. Whenever the forest question was taken up, whether in India or in the colonies, the usual cry was that the matter might be safely left to private enterprise; then, when people began to feel uneasy as to the result, feeble attempts were made to interfere by half-hearted measures, which had for their object to check the further destruction of the forests and the waste of valuable material, without, however, inconveniencing anybody engaged in the business of destruction. It was only when matters had gone from bad to worse that more energetic steps were taken—in other words that, after all, the State did interfere.

It has been shown in parts I. & II. of this volume, that State interference is more called for in the case of forestry than in most other industries, and it has been explained in what manner this can be effected. The Government of India recognised the necessity of determined action many years ago. In many of the colonies the question has been taken up in various degrees. In the mother country the forest question is still in its infancy.

A detailed account of the state of affairs in the several parts of the Empire would doubtless be interesting to many, but to attempt this would be beyond the scope of this book; hence the question of afforestation will only be dealt with in respect of the mother country, and of

India: the former, because it is by far the principal importer of forest produce, and the latter, because up to date, there the forest question has really and honestly been dealt with, thanks to the enlightened views and initiative of that great statesman Lord Dalhousie, sometime Governor-General of British India, and the able assistants whom he secured for the inauguration of his policy. Of the latter, Sir Dietrich Brandis stands out as the centre figure. It was he who organised the Indian Forest Department, and started it on the right lines.

CHAPTER I.

FORESTRY IN GREAT BRITAIN AND IRELAND.

1. *Indirect Effects of Forests.*

In applying the above conclusions to Great Britain and Ireland, it should be remembered that the climate and rainfall of these islands are principally governed by their insular position, which exposes them to strong moist air currents coming direct from the sea. Compared with their effects, those of forests, even if they occupied 20 per cent. of the total area, would be found comparatively small. Again, a great portion of the waste lands in Great Britain and Ireland is covered with heath, and a considerable portion with peat mosses, which are most powerful agents in the retention of water; in this respect the addition of trees would make comparatively little difference; moreover, afforestation would, in many cases, be accompanied by the draining of the soil, which would counteract the effects of forests. Lastly, Great Britain and Ireland get as much rain as they require, and in many parts more than is good. As regards climate and rainfall an increase of the forest area is, therefore, not required.

The next point for consideration is the effect of forests on the regulation of the moisture, on floods, landslips, erosion, etc. If Great Britain and Ireland were situated in a more southern latitude, or removed from the sea,

their configuration, especially that of Scotland, Ireland and Wales, would probably make afforestation a necessity, but owing to the existing climate, the waste lands are naturally clothed with a covering which retains water in a high degree, and binds the surface soil well together. The upper part of the hill ranges is, in many cases, bare, and there afforestation might produce some good effects, but the undertaking, even if the plantings were successful, would never pay, and it could only be justified on public grounds if the damage done by the rushing down of the rain water was great. Damage of this kind occurs occasionally, but on the whole it is not considerable. The rock is in most parts sufficiently consistent, or at any rate covered with a sufficient growth of plants, to resist any appreciable eroding action of the rain water. On the whole, afforestation is in this respect not called for; at any rate, the question is neither urgent nor very important, so long as erosion is not artificially started by the act of man. Damage by floods occurs in some parts, but it will be cheaper to suffer the loss, or to meet it by engineering works, than by the afforestation of unpromising steep hill sides.

The action of forests on winds and the protection which wood lands afford to cultivation, cattle, and useful birds deserve, however, attention. It is well known that the strong sea breezes which sweep over these islands impede, to a considerable extent, the successful prosecution of agricultural operations, more especially along the western coastlands, and any measure which would reduce this baneful effect must be beneficial. Much good could be done in this respect by a judicious distribution over the country of belts and blocks of forest.

2. *Forest Produce Required by the Nation.*

a. General.

Great Britain and Ireland are well supplied with coal and peat, so that the production of firewood is of very little importance; indeed, firewood is almost unsaleable in many parts of the country. The question of the supply of timber and minor forest produce, on the other hand, is of great importance. Although the production of iron is enormous, the imports of wood into Great Britain and Ireland are very considerable, and still on the increase. Large quantities of minor forest produce are also imported, that is to say articles which serve as the raw material in various branches of industry.

The Annual Statement of the Trade of the United Kingdom for the year 1894 shows that the following quantities of timber and minor forest produce were *annually* imported during the years 1890–94.

	Loads.		Value £.
Timber . .	7,628,221	=	17,594,606
Minor forest produce		=	8,997,237
Total annually =	7,628,221	=	26,591,843

The first thing which these figures show is, that the imports of timber have increased since 1883–87 (when they amounted to £15,000,000) by about £2,500,000, and it will be worth while examining the question somewhat in detail. For this purpose the figures for 1894 have been chosen, which approach the annual average of the last five years sufficiently close to serve as samples.

The subjoined statement gives the wood imported during the year 1894:—

57256

TIMBER IMPORTED INTO GREAT BRITAIN

Country whence Imported.	Fir, Hewn and Sawn.		Oak, Hewn, and Staves.		Teak.	
	Loads.	Value, £.	Loads.	Value, £.	Loads.	Value, £.
British Possessions.						
Canada and Newfoundland	1,301,017	3,172,283	22,462	147,948	...	...
West Indian Islands, Honduras, Guiana	...	...	..	...	...	...
Gold Coast and Niger Protectorate	...	...	...	...	...	...
East India and Straits Settlement	...	...	...	...	38,014	404,445
Australasia	3,827	24,557	..	...	...	...
Other British Possessions	25	125	8	50	...	...
Total British Possessions	1,304,869	3,196,965	22,470	147,998	38,014	404,445
Foreign Countries.						
Russia	1,896,370	3,721,027	53,477	144,411	...	...
Sweden	2,053,672	3,830,458	13,425	22,823	...	...
Norway	729,170	1,369,455	25,164	55,332	...	...
Germany	272,140	548,025	40,612	283,161	..	...
Holland	...	...	869	4,499	...	...
Belgium	...	...	...	...	...	...
France	675,865	513,466	697	3,398	...	...
Spain	47,853	35,628	...	...	...	...
Italy	...	...	...	...	...	...
Austria	...	...	5,598	58,827	...	...
Turkey	...	...	...	...	...	...
United States of North America	450,608	1,153,663	78,657	477,046	...	...
Mexico, Honduras, Columbia, Venezuela, West Indian Islands	...	...	...	...	...	...
Portuguese East Africa	...	...	...	...	392	4,320
French West Africa	...	...	...	...	...	...
Siam	...	...	...	...	5,649	54,102
Other Foreign Countries	7,216	14,620	1,892	11,685	278	2,842
Total Foreign Countries	6,132,894	11,186,342	220,391	1,061,182	6,319	61,264
Grand Total	7,437,763	14,383,307	242,861	1,209,180	44,333	465,709
Re-Exported	19,156	69,308	6,813	52,332	4,851	55,275
Net Imports	**7,418,607**	**14,313,999**	**236,048**	**1,156,848**	**39,482**	**410,434**

AND IRELAND DURING THE YEAR 1894.

Mahogany.		Other Furniture Wood.		House Frames.		Miscellaneous.		Total for each Country.	
Loads.	Value, £.	Loads.	Value, £.	Loads.	Value, £.	Loads.	Value, £.	Loads.	Value, £.
...	...	3,944	25,175	4,880	19,520	58,896	187,551	1,391,199	3,552,477
14,313	116,547	618	4,971	...	...	4,210	24,756	19,141	146,274
7,131	62,713	545	4,134	...	...	...	...	7,676	66,847
...	...	4,240	28,937	997	3,989	...	...	43,251	437,371
...	...	8,255	40,648	140	566	...	...	12,222	65,771
327	2,418	205	1,520	396	1,577	27	54	988	5,744
21,771	181,678	17,807	105,385	6,413	25,652	63,133	212,361	1,474,477	4,274,484
...	...	1,759	20,153	2,368	9,473	45,087	75,428	1,999,061	3,970,492
...	...	...	...	22,415	89,661	18,714	34,665	2,108,226	3,977,607
...	...	...	...	692	2,768	5,445	8,058	760,471	1,435,613
1,545	11,423	1,479	14,732	28,998	115,993	8,279	19,445	353,053	992,779
...	...	...	...	15,781	63,125	7,954	37,263	24,604	104,887
...	..	...	...	19,098	76,391	...		19,098	76,391
...	...	2,069	23,864	16,663	66,651	10,219	44,243	705,513	651,622
...	...	...	...	...	...	...	...	47,853	35,628
...	...	298	3,208	679	2,715	...	...	977	5,923
...	...	...	...	1,189	4,755	...	...	6,787	63,582
...	...	1,422	14,245	...		...	...	1,422	14,245
1,842	15,128	52,706	365,681	51,730	206,922	32,638	138,387	668,181	2,356,827
34,802	261,308	7,675	43,107	...	...	...	...	42,477	304,415
...	...	...	...	...	...	...	...	392	4,320
5,018	47,835	595	5,292	...	...	...	...	5,613	53,127
...	...	...	...	...	...	...	...	5,649	54,102
516	4,487	1,298	8,595	1,055	4,219	268	1,047	12,523	47,495
43,723	340,181	69,301	498,877	160,668	642,673	128,604	358,536	6,761,900	14,149,055
65,494	521,859	87,108	604,262	167,081	668,325	191,737	570,897	8,236,377	18,423,539
3,136	41,537	7,338	73,398	6,012	24,047	1,490	10,779	48,796	326,676
62,358	**480,322**	**79,770**	**530,864**	**161,069**	**644,278**	**190,247**	**560,118**	**8,187,581**	**18,096,863**

This table shows the *net* imports to have been 8,187,581 loads valued at £18,096,863. Some of the material, such as teak, mahogany and other furniture woods, could not be produced in Britain, but a detailed examination of the returns shows that there is no reason why the following produce should not be grown in the country:—

	Loads.	Value in £.
Fir . .	7,418,607 .	14,313,999
Oak and staves	236,048 .	1,156,848
House frames, etc.	150,000* .	600,000
Miscellaneous wood	170,000 .	470,000
Total =	7,974,655	16,540,847

The imports of the principal items of minor forest produce will be seen from the following statement:—

Articles.	Mean Annual Imports, 1890—94. £	Imports, 1894. £	Re-export, 1894. £	Net Imports, 1894. £
Caoutchouc, raw	3,240,392	3,272,104	1,801,130	1,470,974
Cork, raw	192,242	163,892	12,262	151,630
Dyeing and Tanning Stuffs, Bark...	176,922	124,904	8,205	116,699
,, Cutch & Gambier	588,041	577,810	222,855	354,955
,, Myrobolans	246,745	305,278	6,287	298,991
Dye-Woods.....	482,409	554,740	34,343	520,397
Gum	1,152,940	1,288,415	788,096	500,319
Gutta Percha	560,750	446,279	70,569	375,710
Turpentine.....	547,126	431,382	31,499	399,883
Wood Pulp.....	1,432,400*	1,432,400	57,264	1,375,136
Rosin	377,270	331,486	10,154	321,332
Total	8,997,237	8,928,690	3,042,664	5,886,026

* Annual average for the years 1890—94 not available.

Most of the items in this list cannot be grown in these islands. The tanning bark and some of the turpentine and

The loads of house frames, etc., have been estimated, as only their value is given in the returns.

rosin might, no doubt, be produced, but they will not be taken into account in the following remarks. The wood pulp, however, can be so produced; its value amounts to £1,375,136, representing 268,577 tons. As it takes, on an average, 3 to 4 loads of wood to prepare a ton of pulp, the manufacture of the imported pulp consumes about 1,000,000 loads of wood. Adding these sums to those of the timber previously given, the total quantity and value of timber now imported, which could be produced in this country, stands as follows:—

	Loads.	Value in £.
Timber . .	= 7,974,655	16,540,847
Timber used in the manufacture of wood pulp, and value of the latter	= 1,000,000	1,375,136
Total	= 8,974,655	17,915,983

In round figures, 9,000,000 loads of timber representing a value of £18,000,000 are now annually imported into Britain, which could be grown in the country. These are large sums, and the question arises whether the land for their production is available, and whether it would pay to grow the timber in this country.

b. Land Available for Afforestation in Great Britain and Ireland.

Broadly speaking, each acre of land could according to quality produce from one to two loads of fir timber annually, and about one load of oak; hence, an area of about 6,000,000 acres would suffice to produce the 9,000,000 loads of timber in question.

The Agricultural Returns for Great Britain for the year 1894, and the Agricultural Statistics for Ireland for 1893, give the following data :—

STATEMENT SHOWING THE MANNER IN WHICH LAND IS USED IN GREAT BRITAIN AND IRELAND.

Classification.	England.	Wales.	Scotland.	Total Great Britain.	Isle of Man and Channel Islands.	Ireland.	Total United Kingdom.
	Acres	Acres	Acres	Acres	Acres	Acres	Acres
Land under field crops, including clover and grass, under rotation..	11,752,929	874,151	3,537,706	16,164,786	96,638	4,080,006	20,341,430
Permanent Pastures	13,127,738	1,982,804	1,354,477	16,465,069	31,412	11,081,919	27,578,400
Total	24,880,717	2,856,955	4,892,183	32,629,855	128,050	15,161,925	47,919,830
Mountain and heath land used for grazing	**1,986,310**	**1,054,968**	**9,409,406**	**12,450,684**	**16,142**	?	**12,468,826**
Total used by Agriculturists	26,867,027	3,911,923	14,301,589	45,080,539	146,192	15,161,925	60,388,656
Woods, Plantations and Nurseries	1,624,985	175,228	907,078	2,707,291	1,761	307,386	3,016,438
Total Area used	28,492,012	4,087,151	15,208,667	47,787,830	147,953	15,469,311	63,405,094
Total Area of Country	32,543,890	4,773,995	19,453,843	56,771,728	193,333	20,706,258	77,671,319
Balance of Land and Water	**4,051,878**	**686,844**	**4,245,176**	**8,963,898**	**45,380**	**5,236,947**	**14,266,225**

This table shows that the area of surplus lands, including inland water, amounts to 14,266,225 acres. Unfortunately it is not known how much of this area is fit for planting. As regards Ireland, it is known that the 5,236,947 acres given in the returns, contain :—

	Acres.
Turf Bog	= 1,191,086
Marsh	= 455,178
Barren Mountain Land . .	= 2,241,285
Total	= 3,887,549

It may be assumed that 2,000,000 acres of this area are fit for planting, and it will not be excessive to assume that of the 9,000,000 acres in Britain, another 2,000,000 acres will be found suitable for plantations,

making so far a total of 4,000,000 acres. Then there are 12,468,826 acres of mountain and heath land in Britain, which are classed as "rough grazing land." Three-fourths of it are situated in the hilly parts of Scotland, where they are used, not only for rough grazing, but also for shooting, yielding in many cases high returns. This land cannot be said off-hand to be available for planting, but on a detailed examination it will, no doubt, be found that a fair portion of it might be planted without thereby interfering with the grazing or the shooting rents. On the contrary, the shelter thus provided to cattle, sheep, and game, may have the opposite effect, provided the plantations are judiciously distributed over the area. On the whole, there seems to be no doubt that the balance of 2,000,000 acres required for the production of the 9,000,000 loads of timber now imported, could be found out of the 12,468,826 acres of mountain and heath land.

In connection with this subject, attention may be drawn to the fact that of late years a decided change has taken place in the manner of using the agricultural lands. It has been stated in the official returns, that between the years 1874 and 1894, the following changes have occurred in Great Britain only :—

—	Area in Acres.		Increase.	Decrease.
	1874.	1894.		
Arable land	18,089,000	16,165,000	...	1,924,000
Pastures	13,178,000	16,465,000	3,287,000	...
Total	31,267,000	32,630,000	1,363,000	...

In so far as the changes are not due to a more accurate collection of statistics, the above data show

that the arable land has, during the last twenty years, decreased by nearly two million acres, and the permanent pastures increased by three and a quarter million acres, resulting in a net increase of agricultural land of 1,363,000 acres. A similar movement, though not so decided, has been going on in Ireland.

During the last few years, however, a further change has occurred, which is illustrated by the following data:—

	Area in Acres in—		Increase.	Decrease.
	1892.	1894.		
Arable land	20,444,577	20,341,430	...	103,147
Permanent pasture	27,533,326	27,578,400	45,074	...
Total	47,977,903	47,919,830	...	58,073

It will be seen that the increase of permanent pasture is no longer equal to the decrease of arable land, the result being a reduction of 58,073 acres in the area of agricultural land under utilization. During the same two years, the number of live-stock (horses, cattle, sheep, and pigs) decreased from 50,500,000 to 46,700,000, or a difference of 3,800,000 head. These later movements are, apart from an unfavourable season in 1893, no doubt due to the continued fall in the price of agricultural produce, caused by an ever increasing competition from outside. If the reduction in the arable land continues, without a corresponding increase in the permanent pastures, considerable additional areas may become available for profitable afforestation.

c. Does Forestry Pay in Great Britain and Ireland?

This question is certainly beset by considerable difficulties, but a fairly accurate answer may be given. From the data given above, it has been calculated that the imported wood, which can be grown in this country, was estimated at the following rates in port:—

		Per load.
Oak, including staves	at	£4 18 0
House frames, fittings, joiners' and cabinet work . . .	at (about)	4 0 0
Miscellaneous wood . . .	„	2 15 3
Sawn fir	„	2 3 5
Fir, in logs	„	1 9 6
Fir, for pit props, and the manufacture of paper pulp . .	„	0 15 2

If it pays to grow fir (in logs and pit props), then it will, no doubt, pay to grow the other descriptions of timber, hence the question will be tested by the former material. Logs of fir and pit props can be grown together, the thinnings being utilized as pit props, and the final crop in the shape of logs. The total yield would, therefore, roughly consist, two-thirds of logs, and one-third of pit props, so that the average value per load would be $\frac{2\,(1-9-6)+0-15-2}{3} = £1\ 4\ 9.$

If the plantations are laid out and treated in the right way, each acre may safely be expected to yield annually 1½ to 2 loads of timber; which would be equivalent to £1 17 1 an acre, valued at 37 shillings net a year, equal to £185 in 100 years. Assuming that the land is

planted with Scotch pine and larch, and treated under a rotation of one hundred years, the following returns * may be expected on an average:—

Thinning at the age of			30	years	=	£1 0 0
,,	,,	,,	40	,,	=	4 0 0
,,	,,	,,	50	,,	=	10 0 0
,,	,,	,,	60	,,	=	10 0 0
,,	,,	,,	70	,,	=	10 0 0
,,	,,	,,	80	,,	=	20 0 0
,,	,,	,,	90	,,	=	20 0 0
Final crop	,,	,,	100	,,	=	110 0 0
		Total				£185 0 0

Placing the cost of planting and fencing at £4 0 0 an acre, the annual cost of tending at 3*s.* an acre, and calculating throughout with 2½ per cent. compound interest, the annual net rental of the soil comes to:—

$$\left[\frac{110+20\times1{\cdot}025^{10}+20\times1{\cdot}025^{20}+10\times1{\cdot}025^{30}+10\times1{\cdot}025^{40}+10\times1{\cdot}025^{50}+4\times025^{60}+1\times1{\cdot}025^{70}-4\times1{\cdot}025^{100}}{1{\cdot}025^{100}-1}\right]\times0{\cdot}025-3$$

= £0 7*sd.* 6. (See p. 154 of volume III.)

In words, land which does not now bring 7*s.* 6*d.* *net* per acre and year, can profitably be planted with larch or Scotch pine for the production of timber and mining props.

If the management is directed towards the production of mining props only, the wood may be cut over at the age of 40 years, and it can be expected to yield a thinning worth £10 at the age of 30 years, and a final yield of £45 * in the year 40. Placing again planting and fencing at £4, the annual cost of tending at 3*s.* an acre,

* After deduction of cost of felling.

and calculating with $2\frac{1}{2}$ per cent. compound interest, the corresponding annual *net* rental of the soil comes to:—

$$\frac{45+10\times 1{\cdot}025^{10}-4\times 1{\cdot}025^{40}}{1{\cdot}025^{40}-1}\times{\cdot}025-3 \text{ shillings}$$

$=11$ shillings.

This means that land situated not further from mines than the nearest seaport, can profitably be used for the production of mining props, provided it does not bring more than 11 shillings an acre, annually, if used for another purpose.

If hitherto home grown timber has not been able to compete with imported timber, the reason must be looked for in the following two facts:—

(1.) The home grown timber is of inferior quality.

(2.) It comes into the market at irregular intervals, and in fluctuating quantities.

Up to date, plantations in this country have been too heavily thinned during the first half of their life, with the result that the boles of the trees are shorter and less clear of branches and knots, than the imported material. Conifers also grow too rapidly in diameter, if heavily thinned early in life, and consequently, produce timber which is inferior in lasting qualities to that imported from the Baltic.

The second fact prevents the development of a regular timber trade combined with superior methods of converting the material, and the establishment of forest industries; in short, the whole business is too haphazard.

These drawbacks can be removed only by improved sylvicultural methods, and a more systematic management of the forests, a subject which will be again referred to.

d. Uncertainty of Future Supplies.

The 9,000,000 loads of timber imported annually, including 1,000,000 loads used in the manufacture of wood pulp, which could be grown in the United Kingdom, came in round numbers from the following countries:—

From Canada	1,447,000	loads.
„ Australasia	3,000	„
Total British possessions	1,450,000	„
From Sweden	2,300,000	„
„ Russia	2,000,000	„
„ Norway	1,400,000	„
„ France	700,000	„
„ Germany	360,000	„
„ Other European Countries	140,000	„
Total foreign countries in Europe	6,900,000	„
From the United States of America	650,000	„
Grand total	9,000,000	„

The United Kingdom received about 1½ million loads from British colonies, and about 7½ million loads from foreign countries over whose forest policy the British Government has no control. The question thus arises, are these countries likely to keep up the supply? The reports received from Canada are not encouraging. Enormous areas of timber forests have

been destroyed of late years, and the United States may at any date attract the surplus supply which is still available in Canada. It is beyond the scope of this work to discuss the question, in how far the British Government can influence the Government of Canada in introducing an efficient system of forest conservancy. The imports from this source have been fairly steady of late years.

The supplies received from the United States of America represent probably, as far as their bulk is concerned, material which came originally from, or is replaced by, Canada; hence it may be safely predicted that this supply will disappear, because the United States have to import timber on a large scale for their own requirements.

The imports from France are believed to represent chiefly pit props received from the pine forests situated to the north and south of Bordeaux. The supply has, during the years 1883—95, increased by about 100 per cent.

The imports from Germany are about the same as eight years ago. The bulk of the German forests is under systematic management and control, and it is believed that future supplies to this country could be increased, especially from the forests in East Prussia. At the same time Germany imports more timber than it exports.

In Sweden, Norway, and Russia the forest conservancy measures so far introduced do not warrant a sustained yield from these countries. Of the Swedish forests only 20 per cent., and of the Norwegian 12 per cent. belong to the State, while little or no control is exercised over

the rest of the areas. The United Kingdom has lately received nearly 6,000,000 loads from the above-mentioned three countries, including wood used for pulp. No other countries are known at present which could replace the supplies hitherto received from the Baltic, if they should fail. India has nothing to spare, except a certain quantity of Teak and some fancy woods, which would be too expensive to replace the cheap woods now received from nearer home. Australasia can probably do little or nothing to help, and the African colonies are as yet a *terra incognita* in this respect.

On the whole, future supplies of timber to this country in sufficient quantity are by no means assured; there is, in fact, so much doubt about their continuity, that any woods now planted in the United Kingdom may reasonably be expected to yield a fair return by the time they become ripe for the axe.

3. *Labour.*

The labour question in connection with afforestation is of some importance in these islands. If the forest area were increased by 6,000,000 acres during the next twenty years, it would be necessary to plant annually some 300,000 acres, which would fully employ at least 15,000 labourers (one labourer for twenty acres), corresponding to a population of 75,000 people. After the forests had been created, they would give steady employment to perhaps 100,000 labourers, corresponding to a population of half a million of people, apart from special forest industries, which the existence of extensive forests tends to create, and the labour

required in the fashioning and transport of the timber. Large as these figures are, they show that forests give but small employment, when compared with the cultivation of field crops on equal areas; it follows that, as regards the labour question, no lands required for field crops can be made available for forests. The latter must, in this respect, be restricted to surplus areas, as long as forest produce is obtainable at a reasonable rate from abroad. If, however, large numbers of people are in want of work, it would be a judicious measure to give them employment by afforesting available waste lands, a consideration which is of special importance in Ireland. With the exception of the duties performed by the administrative staff, the work connected with forest operations can be made to fit in with agricultural occupation, and the small cultivator, especially in the poorer parts of the country, can take advantage of every spare day to earn a day's wages by work in the forest, and so add to his income, which would be a substantial help in enabling him to meet the payment of rent, taxes, etc. As regards Ireland in particular, afforestation would prove to be a useful auxiliary in solving the land question, and through it bringing contentedness to that country.

4. *Conclusions.*

In summing up, the following principal conclusions may be drawn in respect of Great Britain and Ireland.

(1.) As the imports of wood and other forest produce are very great, and as it is doubtful whether sufficient supplies can be permanently obtained

from other countries, the extension of the forest area can be strongly recommended, provided it is carried out on surplus lands. The additional woodlands may reasonably be expected to yield fair returns on the invested capital, if the work of formation and administration of the forests is done in an economic manner.

(2.) The surplus area in the United Kingdom is so great, that extensive areas can be set aside for forests without trenching on the land required for field crops and permanent pasture.

(3.) The tendency of forests to reduce the temperature of the soil and air, and to increase the relative humidity of the air and precipitations is of subordinate importance in these islands, as they are, owing to their geographical and sea-bound position, subject to influences, in comparison with which those of forests are small.

(4.) The increase of the forest area will act very beneficially in reducing the effects of winds on adjoining lands under cultivation, and in affording shelter to cattle, game and useful birds.

(5.) The extension of the area under forest will provide additional work, without interfering with existing sources of occupation.

It will be seen, that a fair field for judicious enterprise exists in the extension of the woodlands of Great Britain and Ireland, on areas which do not yield a fair return if cultivated for field crops, or used as pastures, or deer and game preserves. As regards the latter, partial

afforestation may even increase the returns which are now derived from such lands.

The question then arises, what can be done to stimulate the afforestation of surplus lands. It has already been shown that lands which do not give a net rental of say 8 shillings a year, can profitably be used for the production of forest crops; but this will only be possible under the following two conditions:—

(1.) Afforestation requires a certain outlay at starting, and involves foregoing an income from the land until the woods commence yielding a return.

(2.) The knowledge of systematic forestry must be made accessible to those engaged in the formation and management of woodlands worked on economic principles.

Hitherto both these matters have, practically, been left to private exertions, but now that agriculture has fallen low, many voices have been calling upon the State for assistance, not only in this respect, but as regards industries generally. The special facilities given to British industries by coal and iron, the insular position of the country, and the natural energy and practical sense of the people have made the United Kingdom the greatest manufacturing country of the world, and have brought unbounded wealth to the nation. As long as this condition lasted, State assistance was not wanted. But latterly it has been felt that outside competition is steadily increasing, and that other nations are making more rapid progress than Britain. The attention of Englishmen has been increasingly directed towards discovering the causes which are gradually bringing about that change. Apart from the effects of free trade in Britain *versus* protection

in other countries, it has been found that the technical education of the people has more rapidly advanced in other European countries than in the United Kingdom, brought about by judicious action on the part of the State authorities. Englishmen, until lately, have been averse to such action, but now a change is taking place. Leading men and journals call loudly for State action, so as to prevent, as far as possible, the ruining of many of the British industries threatened by the development of scientific research, technical instruction, and judicious State action on the Continent. It has been publicly stated that* "both in Germany and France it is held an "essential part of the duty of the State to second, and "not only to second, but to stimulate and direct the "efforts of private enterprise. In Britain, State assist- "ance is regarded with distrust and disfavour. The "home industries in many cases languish for want of "intelligent direction. Agricultural distress might be "alleviated were the State not wanting in promoting "the education of the population in the minor agricul- "tural arts, and the organisation of agricultural in- "dustries after the manner in vogue on the Continent. "Although nothing can excuse the short-sighted folly "of our manufacturing classes in not providing for "scientific research in the various branches of industry, "*yet it is the duty of a wise Government to take measures* "*to counteract the folly of classes, when it threatens the* "*general interest.* In one word, Great Britain stands at "this moment in imminent danger of being beaten out of "the most lucrative fields of commerce, simply because "it does not recognise, while other nations do, the value

* See the *Times* of the 27th November, 1895.

"of scientific organisation in the field, in the workshop, "in the laboratory, and in the conduct of national policy."

It need hardly be pointed out that these views completely agree with the principles laid down in part II. of this volume in respect of forest policy. State aid is necessary if the imports of timber from foreign countries are to be replaced by material produced in these islands. Such assistance can be given in a variety of ways, amongst which the following may be mentioned:—

(1.) Assistance should be afforded for the equipment of forest schools, competent to teach economic forestry as now elaborated by research.

(2.) The limited area of Crown forests should, as far as possible, be managed on economic principles, so as to serve as patterns to private proprietors.

(3.) Advances should be made to landed proprietors who are desirous of planting land.

(4.) Surplus areas may be acquired by the State in certain parts of the country, and put under forest.

Beginning with the education of wood managers, it should be mentioned what has been done in the past. There is a fully-equipped forest school connected with the Royal Indian Engineering College, Coopers Hill, where candidates for the Indian forest service and occasionally for the colonies are educated. A commencement at forest education has been made at Edinburgh, Durham College of Science, and a few other places; some of these institutions have lately received small grants in aid from Government. It can, however, hardly be maintained that these institutions meet the requirements of the case. Hitherto, British woodlands have been treated more from the

æsthetic point of view than for profit. The consequence was, that woodcraft centered in arboriculture, rather than in sylviculture, with the results indicated on page 111. None of the existing establishments, where wood managers for employment in Britain can now acquire some knowledge of their profession, are in a position to teach scientific and systematic forestry as understood in Germany and France, where the profession has been brought to the highest state of development. What is wanted, is the establishment of one or more institutions, where wood managers can be thoroughly trained. Efforts have been made to do this by private co-operation, but so far they have failed, and, unless the State steps in, no fruitful results can be expected for some time to come. If, then, the long hoped-for Minister of Education becomes a reality, he should take steps to start and equip one or more forest schools, where students can attain to that proficiency which alone assures favourable financial results. The most convenient plan would probably be to attach that school to an existing educational establishment, such as the Universities of Oxford, Cambridge, Edinburgh and Dublin. There, instruction in the auxiliary sciences is already provided for, and all that is wanted, is the establishment of chairs for forestry, and special courses of forest botany. A beginning in this direction has been made at Edinburgh and a few other places, but it requires considerable development.

But something more is wanted than theoretical instruction. Economic forestry, though based on science, is an eminently practical business, and instruction in the field must also be provided. There must be forests which are managed on the right lines, where students

find the theory of economic forestry practically illustrated. Such forests are at present wanting in Great Britain and Ireland, and this so much so, that the students at Coopers Hill College are regularly sent every year to the continent to work in French and German forests. If forestry in Britain is to become a living thing, this must be changed. As a commencement, the forest areas under the control of the Commissioners of Woods and Forests, in so far as they lend themselves for the purpose, should be brought under systematic management at the earliest possible date. This can be done by attaching to their office a forest expert, whose business it would be to draw up schemes of systematic management, based on economic principles, for all areas where the Commissioners have a fairly free hand, and then to see the schemes duly carried out. In this way a number of pattern forest estates can be created, where students of the profession can receive their practical instruction. As soon as the more favourable financial results brought about by this measure make themselves felt, private proprietors would quickly follow the lead, thereby bringing about the introduction of economic management on an extended scale.

Even with the best intentions proprietors of surplus lands are in many cases not in a position to plant. That operation involves an initial outlay, which may not be at their disposal, and they must forego an income from the land, however small, until the plantations commence to yield a return. It is a question worth considering, whether the State could not help by making suitable advances. The principle has been already admitted in the case of agricultural holdings, where the State, in

certain parts of the country, advances money, which is repaid, capital and interest, in a number of years by annual payments of five per cent. on the amount advanced. The agriculturist can do this, as he reaps his first crop at the end of a year. In the case of forests the returns do not commence until after the lapse of a series of years, and many proprietors could not afford to pay at once five per cent. on any advance made for the purpose of planting. To meet this difficulty, advances might be made on the following conditions:—

(1.) The amount advanced shall be sufficient, and not more, to meet the cost of draining, fencing and planting.

(2) The proprietor shall pay 2½ per cent. (the rate at which Government can borrow) annually on such advance, until the plantations begin to yield a return; commencing from that moment the annual payment should be raised sufficiently to repay the capital and interest within a limited period of time.

(3.) Government will have a lien on the plantation until the advance is paid back, and consequently a suitable control over the management.

If any such scheme were adopted, the proprietor, instead of meeting the whole cost of the undertaking at once, would only have to pay interest at 2½ per cent. on the outlay and forego the annual income (if any) so far derived from the land, until the plantations commence to yield a return.

It may not be out of place to explain here, that such an arrangement would be specially acceptable to a proprietor, who possesses already a certain area of wood-

land and surplus area available for planting. Putting the latter under forest would enable him to cut, at an early date, more freely in the former, so that he could easily meet the interest on the loan, without thereby endangering the systematic and economic management of the whole estate.

Lastly, the State might acquire suitable lands, and put them under forest. Ten years ago, the author pointed out* how such a measure might become a powerful auxiliary in settling the Irish land question, and what he then stated holds good to-day. Now the agricultural shoe is also pinching severely in Great Britain, and in many cases blocks of land might be acquired and added to the Crown estates, which would otherwise remain useless, or nearly so.

The ever increasing flow of people from the country into the large towns is sure to become the most important question, with which the State will have to deal in the early part of the approaching new century, and any measure now taken, which will retard that movement, must act highly beneficially. Such a measure would be the afforestation of surplus lands, which would give additional work in the country, and insure to the people a more wholesome existence than they will find in the slums of the large towns, especially when want of work has forced them to join the large army of the "unemployed."

These and allied questions demand serious attention, because they are calculated to assist materially in

* See his pamphlet on Afforestation in Great Britain and Ireland, written at the request of the late Viceroy of Ireland, Lord Carnarvon, and printed in January, 1886, by Alex. Thom & Co., Queen's Printers, Dublin.

maintaining the proud position which the United Kingdom of Great Britain and Ireland occupies in the world. The English nation could afford to rest on its oars for a certain period of time, because it was ahead of others; but now the latter are coming up fast, and threaten to catch up, if not to pass, Britain. A fresh spurt on the part of the latter is urgently wanted, for standing still, beyond an occasional rest, must inevitably lead to defeat.

CHAPTER II.

FORESTRY IN BRITISH INDIA

It would be beyond the scope of this work to give here a detailed account of all those points on which the general forest policy of India must depend. A few short notes on the physical configuration of the country and its climate are, however, indispensable before dealing with the forest question itself.*

India is a very large country; it extends from the 8th to the 35th degree northern latitude, and from the 67th to the 100th degree eastern longitude. Its length from north to south is 1920 miles, and its greatest breadth including the newly-acquired territory of Upper Burma is about the same. On the whole, India proper is of a triangular shape, the Himalayas forming the base on the north, while the southernmost point is Cape Comorin. The triangular peninsula has the Arabian Sea on the west, the Indian Ocean on the south, and the Bay of Bengal on the east. Burma forms a separate strip of land on the east of the Bay of Bengal. The total area of the Indian Empire is given as 1,560,000 square miles, or about thirteen times that of the United Kingdom, and the population as 287,000,000, or more than seven times that of the United Kingdom

* Compare The Statistical Atlas of India, 1886

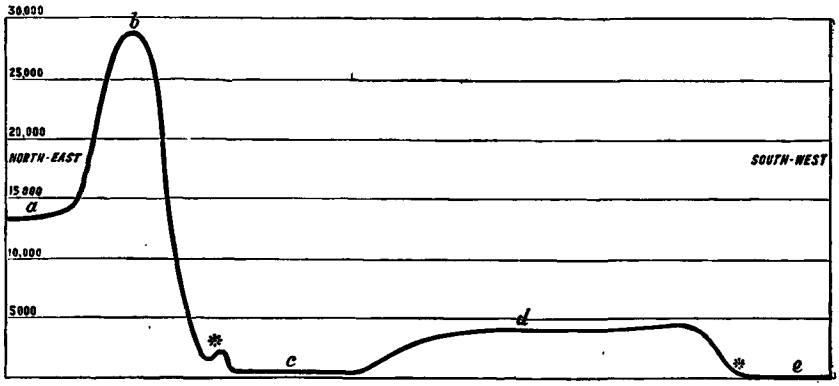
1. *Physical Configuration of the Country.*

The physical configuration of India is very peculiar. Generally speaking, apart from Burma, the country may be divided into three great sections: the Himalayas, the Indo-Gangetic plain and the Peninsula.

The Himalayan range stands out like a lofty wall on the north, separating India from the high plateau of Thibet. Commencing in the west it runs, first in a south-easterly and then in an easterly direction from one end of India to the other; both on the west and the east, other ranges run almost due north and south. The space within these three ranges, and immediately to the south of the Himalayas, forms a broad belt of low land, commencing in the west at Kurrachi on the Arabian Sea, including the whole of Sind, the Punjab plains, the greater part of Rajputana, the North-Western Provinces, Oudh, Behar and Lower Bengal down to the Sunderbuns beyond Calcutta, on the Bay of Bengal. This belt of alluvial land, not more than a few hundred feet above the level of the sea, is the richest part of India.

Proceeding across this belt of low land in a southerly direction, stiff escarpments are met, indicating the commencement of the great highland plateau of the Indian Peninsula, which, at elevations varying from 2000 to 8000 feet, extends to the southern extremity of India. A section drawn from the Thibetan plateau in a south-westerly direction until it reaches the Indian Ocean at Travancore, would present the shape given in

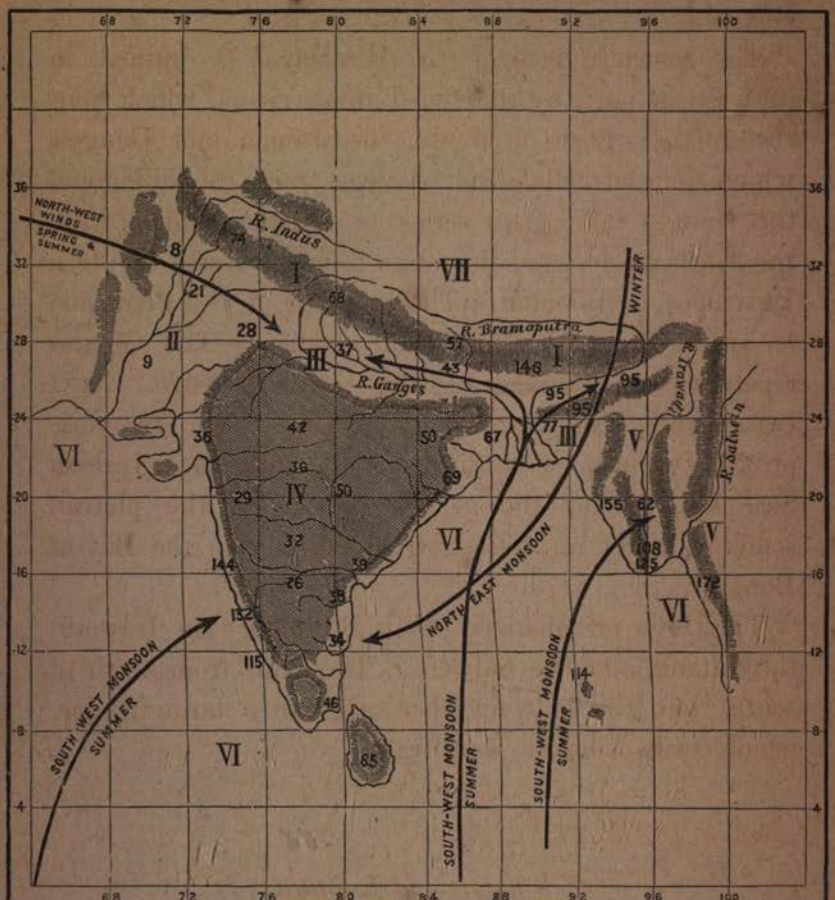
the subjoined sketch, except that the elevations have been exaggerated:—



a. = Thibetan plateau, mean height about 14,000 feet.
b. = Himalayas, maximum height 29,000 feet.
c. = Indo-Gangetic plain, height a few hundred feet above the sea.
d. = Peninsula, height varying from 2,000 to 8,000 feet.
e. = The Sea.
* = Points where the clouds coming from the sea must rise, cool and drop their moisture.

The sketch map on the next page gives an idea of the extent of each of the regions.

The river system of India next claims attention. It is a curious fact, that India receives the drainage of both slopes of the Himalayas. At the back of that mountain chain two great rivers take their rise in close proximity of each other; both run parallel to the Himalayas, the one in a north-westerly and the other in an easterly direction. The former breaks, after some time, through the Himalayas and emerges into the Punjab plain as the River Indus, finding its way, through Sind, into the Arabian Sea. The second river, after running for hundreds of miles to the north of the Himalayas, also breaks through that mountain chain and appears in Upper Assam as the Bramaputra, which proceeds



I. Himalayas. III. Ganges Plain. V. Burma.
II. Indus Plain IV. Peninsula. VI. The Sea.
VII. Thibetan Plateau. 8, 9, 21. Mean annual Rainfall, in inches.

down the Assam valley, through Lower Bengal, and joins the Ganges shortly before reaching the Bay of Bengal.

The southern face of the Himalayas is drained, in its western part, by the five Punjab rivers, which join the Indus. East of Simla, the Jumna and Ganges, which join at Allahabad, emerge from the hills, and the Ganges takes in a series of streams which drain the southern slopes of the range from the North-Western Provinces to Bhootan. The drainage of the Peninsula is arranged in the following manner:—The Ganges receives the drainage of the northern edge. Next two rivers, the Narbada and Tapti, run in close proximity, in a western direction, into the Arabian Sea, but by far the greater portion of the plateau sends its water in an eastern direction into the Bay of Bengal.

The three principal rivers in Burma are the Irawadi, the Sittang, and the Salwein. They run from north to south, but the Salwein also takes in a large feeder, which comes from the south-east.

2. *Climate and Rainfall.*

Owing to the great extent of country included in India and the varying conditions prevailing in the several parts, it is impossible to speak of the climate of India; it would be more correct to speak of the "*climates*," of which the following four types may here be indicated:—

(1.) The climate of Tropical India.
(2.) „ of North-Western India.
(3.) „ of North-Eastern India.
(4.) „ of the Himalayas.

About one-half of the area of India, comprising the greater part of the Peninsula and Burma, is situated south of the tropic. These are the hottest parts of India, as far as the average of the whole year is concerned; but the highest temperature is found further north. The early arrival of the summer monsoon rains mitigates the summer temperature in tropical India; on the other hand this region enjoys little or no cool season.

The second type of climate is found to the north of the tropic in the dry and almost rainless plain of the north-western corner of India, comprising the area which is traversed by the River Indus. Here the highest summer temperature is found, due to a greater length of day and a later arrival of the summer monsoon rains, than in tropical India; it is to some extent compensated for by four or five cool and even cold months during winter, representing at that time a climate which has been compared with a south Italian winter.

The third type of climate is found in Assam and north-eastern Bengal. Here humidity of the air reigns supreme; although there is a distinct summer and winter, in either case the extremes of temperature are moderated by the effects of a relatively large quantity of moisture in the atmosphere, which produces fogs in winter, and interferes in summer with the full effect of the sun's rays on the land.

Finally, the Himalayan mountains present, according to the elevation and position of each locality, a more or less temperate and even Alpine climate, with frost, snow, sleet and bitter winds in winter and a moderate heat in summer.

Between these four types any number of modifications are to be found. However large their number may be, and however much the various climates may differ, they are, apart from elevation, the result of a system of atmospheric changes, which are comparatively simple and regular. The main springs of the Indian climates are the following:—

(1.) The extensive plains and table lands of India are in spring and summer heated to a much higher degree than the surrounding sea; while during winter the air overlying the sea is warmer than that over the land, from which at that season of the year more heat radiates than it receives from the sun. The results are sea breezes during summer and land breezes during winter.

(2.) The greater or smaller tendency with which moisture laden air presses during spring and summer from the south towards India.

(3.) The effect produced by the snowfall of the Himalayas on the movement of dry air currents coming from the north-west and penetrating into the Peninsula.

It will be useful to enter somewhat into the details of these phenomena. In spring, which shall here comprise the months of March, April and May, the highest temperature is found over the centre of the

Peninsula (Nagpur, Hyderabad), while it falls as much as 5 to 10 degrees in proceeding towards the sea on the east and west, and about 10 degrees proceeding to the foot of the Himalayas or to the Punjab plain. The effect is, that the air over the centre of the Peninsula expands, lifts the higher layers of air, causes them to flow away on all sides, and produces a centre of comparatively low pressure. Into this centre presses the heavier atmosphere from the surrounding country, especially from the sea, causing the sea breezes so characteristic of the spring months.

These air currents deviate however from their original course in consequence of the law that everything moving on the northern hemisphere presses towards the right. The consequence is, that the winds which hit the Madras coast at this time of the year are mostly south-easterly breezes, those which hit the southern half of the west coast have a south-westerly direction, while those which hit the land to the north of Bombay assume gradually a more and more north-westerly direction. These phenomena have the result, that Madras and the southern part of Bombay are passed over by moist sea winds, which drop a portion of their moisture, producing a rainfall of from 3 to 6 inches during this period. The above-mentioned north-westerly breezes, however, descend from the table land of Baluchistan; they are dry and become more so in passing over the heated plains of Sind, Cutch and Kathiawar. These are the breezes which are known as the hot winds in the Bombay Presidency, in North-Western and Central India. At times they find their way as far as Bengal and Orissa, and far down into the Peninsula.

Up to May the sea winds are light, and they bring only a moderate amount of rain, as the air is then drawn chiefly from the sea immediately surrounding the Peninsula. With the advancing season towards the end of May, the winds become stronger and stronger, bringing more and more rain, until, in the course of three or four weeks, they have invaded the whole of the west coast of India and the northern and eastern coasts of the Bay of Bengal, an event which is known as the burst of the monsoon. Now the air is drawn from more distant equatorial regions, the great reservoir of moist air.

The strength of the monsoon rains differs greatly in different parts of India; it depends on the configuration of the country and the extent to which the sea breezes succeed in overcoming and pushing back the north-westerly air currents. The monsoon currents enter the Bay of Bengal from the south-west and they strike against the coast of Tenasserim in full force, rise, and pour out a copious rainfall. This holds good in a varying degree along the coast of Burma, in Chittagong, Cachar, and Assam. Along this line the rain clouds meet with hill ranges at moderate distances from the shore, which cause them to rise and drop their moisture, while the Lower Bengal plain receives a somewhat smaller rainfall. After passing through Lower Bengal and on approaching the Himalayan chain, that mountain-range opposes itself to the course of the current and divides it into two parts. The larger part continues its north-easterly course and hits full on the Garo, Khasi and Naga hills, producing the highest rainfall in the world (about 500 inches at Cherrapunji), and finally giving

a considerable rainfall to the Assam valley. The smaller part of the divided current is diverted towards the north-west and west, sweeps, and plentifully waters the face of the mountains and spreads a certain amount of rain over the plains of the North-Western Provinces and Oudh. Here then the summer monsoon comes from the south-east, but it is occasionally displaced by a westerly or north-westerly current, when a shorter or longer suspension of the rainfall occurs, a phenomenon which will be again referred to.

On the west coast of the Peninsula the monsoon blows directly athwart the coast line. As the western part of the Peninsula rises very rapidly from the sea to an elevation of up to 8000 feet at the Ghat range, the clouds are forced to rise, to cool and to drop an enormous amount of rain. At the same time the western edge of the peninsular plateau is its highest part, and the clouds, or what remains of them, having overcome this, descend again in their easterly progress; hence the rainfall diminishes rapidly on the eastern side of the Ghats to about one-sixth of that on the western slopes; this extends over a strip of 100 to 200 miles in breadth, and comprises part of the Deccan, the Mysore table land, and the Carnatic, areas which are much subject to drought.

Between the easterly course of the peninsular monsoon and the westerly course of the wind which, diverted by the Himalayas, rushes up the Gangetic plain, lies a broad belt of debatable ground, comprising part of the Central India States, the Satpura Range, the greater part of the Central Provinces, the table land of Chutia Nagpur, Orissa, and western Bengal. In this

broad belt the rainfall is higher than to the south or north-west of it, chiefly because numerous storms, generated near the coast of Bengal, travel along it from east to west, their passage being accompanied by heavy rain.

The country which lies to the north-west of this belt is, again, under the effect of the western branch of the monsoon; part of this passes through Gujarat, Rajputana, Cutch, and Sind, towards the Punjab, where it disgorges varying quantities of rain according to the configuration of the country. On the whole, however, the strong air current from the west and north-west becomes more and more dry on proceeding north, as it no longer comes from the ocean, but successively from Arabia, Persia, Baluchistan, and Afghanistan; hence the rainfall decreases rapidly on proceeding north from Bombay.

As long as the sea winds are sufficiently strong to keep in check and even force back the north-westerly winds during summer, all is well; but every now and then the reverse is the case, that is to say, the north-west wind forces back the sea winds, and proceeds further and further east and south-east into the North-Western Provinces, Behar, and even Bengal and Orissa, or it forces its way down into the Peninsula. If it keeps its sway over the sea winds for some period, a failure of the monsoon rains is the consequence, an event which is followed by scarcity or famine. It is believed that the strength of this dry air current from the north-west is intimately connected with the snowfall on the Himalayan ranges; when that fall is heavy the north-west winds are strong and *vice versâ*. Further observa-

tions seem, however, necessary to establish the absolute correctness of this view.

The copious watering of the surface of the land, in its turn, reduces the temperature, so that in some parts of the country the rainy season is actually the coolest time of the year. Indeed this reduction is almost proportionate to the rainfall. Hence, districts which receive little or no rain, such as Sind, Western Rajputana, the southern part of the Punjab, and also the Carnatic, show the highest temperature during summer. On the other hand, the temperature of Assam is comparatively little affected, because here rain falls copiously even in spring.

In September the monsoon commences to decline, but in Bengal, Assam, and Burma the rains last well into October. In the beginning of the latter month the winds in the western part of the Bay of Bengal begin to blow from the north-east, and now for the first time the hitherto scantily watered Carnatic receives a copious rainfall; these rains go on until December, when they gradually move southwards to Ceylon. They are followed by a dry steady north-east wind which gradually extends over the whole Bay of Bengal, and is known as the north-east monsoon. An easterly wind takes at that period also possession of the Arabian Sea.

Meanwhile in Northern India the temperature, after a temporary slight rise on the cessation of the rains, has fallen rapidly during November and December, producing a cool air and cloudless skies. About the end of the year, however, clouds begin to gather on mountain peaks, warmer breezes from the south set in, the skies become overcast, followed by a fall of rain, or snow on the hills.

These winter rains are most frequent in the Punjab and the north-western Himalayas, but occasionally they extend also to Bengal, Rajputana, and Central India. They become more frequent in January, February, and March. And then a new round of seasons sets in.

In the January number of the Journal of the Meteorological Society of London, Mr. John Elliot has given the results of certain observations made in 1893, from which he concludes that the snowfall on the north-western Himalayas is due to storms and air-currents generated in Persia. He is also of opinion that the south-west monsoon is a continuation of the south-east trade winds, which push up into India, and not due to the climatic conditions of India. Further extensive observations are, however, necessary to place these opinions beyond doubt.

It is almost impossible to give in a limited space an adequate idea of the endless differences in the climate and rainfall. By way of illustration, the following table is added, in which a series of main groups have been formed. More detailed data must be looked for in the Reports of the Meteorological Reporter to the Government of India, from which the subjoined table has been compiled :—

ABSTRACT SHOWING THE CLIMATE AND

SPRING = *March, April, May.*

SUMMER = *June, July, August.*

Region.	TEMPERATURE, IN DEGREES FAHRENHEIT.				
	Spring.	Summer.	Autumn.	Winter.	Year.
Himalayas . .	59	71	58	42	58
Indus Plain . .	83	90	77	60	77
West Gangetic Plain . .	84	87	77	62	78
East Gangetic Plain and Assam . .	80	83	78	65	77
Peninsula: Northern Edge . .	82	80	73	62	74
Peninsula: West Coast and Ghats	78	74	74	72	75
Peninsula: Centre	88	82	77	73	80
Peninsula: East Coast . .	85	85	81	77	82
Burma . . .	83	79	79	73	79
Bay Islands . .	82	80	80	79	80

RAINFALL OF THE DIFFERENT PARTS OF INDIA.

AUTUMN = *September, October, November.*

WINTER = *December, January, February.*

Region.	Mean Annual Vapour Tension, in Inches.	Mean Annual Relative Humidity in per cent. of Saturation.	RAINFALL, IN INCHES.				
			Spring.	Summer.	Autumn.	Winter.	Year.
Himalayas . .	·332	73	11	61	16	5	93
Indus Plain . .	·483	47	2	14	3	2	21
West Gangetic Plain . .	·569	62	2	26	8	1	37
East Gangetic Plain and Assam . .	·748	80	15	43	17	2	77
Peninsula: Northern Edge . .	·477	54	1	31	9	1	42
Peninsula: West Coast and Ghats	·700	79	6	103	22	1	132
Peninsula: Centre	·561	56	3	22	10	1	36
Peninsula: East Coast . .	·738	67	5	12	18	3	38
Burma . . .	·787	77	14	81	29	1	125
Bay Islands . .	·871	81	20	43	39	12	114

3. *Distribution of Forests.*

If such evidence, as is now available, can be relied on, the greater part of India was in former times covered with dense forests. In those days the country was probably more fruitful and the climate less fierce than now. In the fourth century Fa-Hian, the great Chinese traveller, described the climate as neither hot nor cold. Subsequently, settlers opened out the country along fertile valleys and streams, but the destruction of the forests on a larger scale was done by nomadic tribes, which, moving from pasture to pasture, fired alike hills and plains wherever they went. This lasted for many centuries. With the advent of British rule, the destruction of the forests became more rapid than ever. The order of the day then became "extension of cultivation at the cost of the still existing forests," a process which was carried on for many years, without any enquiry as to the ultimate effects. To this was gradually added an increasing demand for timber, and pasture for rapidly multiplying herds of cattle, which roamed far and wide over the remaining forests. To crown the edifice, Railways then came, and with their extension the forests disappeared with greater rapidity than ever, partly on account of the increased demands for timber and firewood used in construction, and partly on account of the fresh impetus given to cultivation along the lines.

Ultimately, when failures to meet the demands for public works were brought to notice, it was recognized that a grievous mistake had been made, in allowing the forests to be recklessly destroyed. At first, half-hearted

measures were adopted to stop the mischief, and when their insufficiency was recognized, a special State Department was organized to grapple with the existing evil. This change of policy was due to the action of Lord Dalhousie when Governor-General of India.

The first duty of the new Department was to ascertain the extent of the remaining forests, and more especially that portion of them which was still the property of the State. India is a country of extremes as far as climate and rainfall are concerned. The latter more especially governs the natural distribution of the forests. While Jacobabad, in Sind, has a rainfall of 4 inches a year, Cherrapunji, in the Khasi Hills, can boast of a fall exceeding 500 inches a year. Where rainfall and temperature are favourable, the reproductive power of the forests is great; where they are unfavourable, reproduction proceeds only at a slow rate. During the long continued struggle between human action and the effort of self-preservation on the part of the forests, the latter succumbed wherever the climatic conditions were unfavourable; hence, what remained of forests, when the Indian Forest Department was started, was situated in the localities with a heavy rainfall, or where a scanty population had carried on only a feeble warfare against the woodlands.

Again, the nature of the rainfall governs the character of the forests. Where the monsoon rains are heavy, the country is generally covered with evergreen forests; where the rainfall is less copious, the forests are deciduous; under a still smaller rainfall the forests become sparse and more dry, and gradually end in deserts. Thus the evergreen forests are found chiefly along

the moist coast of the Peninsula, in the coast districts of Burma and Chittagong, and along the foot and lower slopes of the eastern Himalayas. The deciduous forests occupy the greater part of the Peninsula, and of Burma away from the coast; they are the home of the teak, sal, sandal-wood, red sanders, iron-wood, padouk, and others. Dry forests are found in Rajputana and the Punjab, and they gradually disappear in the deserts of Sind.

With rising elevation in the hills, more especially in the Himalayas, the forests become gradually temperate and then Alpine. The other extreme are the tidal forests found along the greater part of the coast of India and in the deltas of the rivers.

4. *Area of Forests.*

India is not all British territory; a large portion belongs to native rulers. Including the newly acquired territory in Upper Burma, the total area is divided in the following manner:—

—	Area in Square Miles.	Population.	Density of Population per Square Mile.
British Territory .	964,993	221,000,000	229
Native States . .	595,167	66,000,000	111
Total . .	1,560,160	287,000,000	184

These are vast areas. Nevertheless, a considerable amount of statistics has been collected in the British territory, but less is known regarding the forest areas in the Native States. On the whole it may be said, that about 25 per cent. of the British territory is covered with forest of some kind, and the same propor-

tion may perhaps hold good as regards the Native States.

In several Native States forest conservancy has been commenced in a serious manner, but in others little or no control has hitherto been exercised over the forests. In British territory rather more than half the forest area belongs to the State, and the rest to private persons. The State control over the latter is at present nil or nominal.

The management of the State forests has undergone a great change during the last forty years. Of the total area of Government forests, which may perhaps amount to some 100,000,000 acres, 80,000,000 have been brought under the control of the Forest Department. Of this area 43,000,000 are so-called *reserved* State forests, that is to say, areas which, under the existing forest law, have been set aside as permanent forest estates, while the remaining 37,000,000 are either *protected* or so-called *unclassed* State forests. These areas together comprise about 13 per cent. of the total area of India. Somewhat more than half the area are strictly preserved and systematically managed forests. The rest of the area enjoys as yet only a limited protection, but it rests with the State to perfect that control at any time, as far as existing rights allow of this being done.

The subjoined table gives the details for the several provinces, taken from the official returns for the year 1892–3, received in December, 1894:—

Province.	Government Forests under the control of the Forest Department, on the 30th June, 1893, in Acres.					
	Reserved.	Protected.	Unclassed.	Total.	Percentage of Total Area of Province.	Average per Head of Population.
Bengal	3,650,000	1,965,000	2,582,000	8,197,000	9	·11
North-Western Provinces and Oudh	2,396,000	60,000	31,000	2,487,000	4	·05
Punjab	1,117,000	127,000	2,629,000	3,873,000	6	·19
Central Provinces	12,559,000	...	250,000	12,809,000	23	1·19
Burma (Lower)	3,706,000	...	...	3,706,000	7	·80
,, (Upper)	1,452,000	15,834,000	...	17,286,000	35	5·87
Assam	2,321,000	...	4,569,000	6,890,000	24	1·26
Coorg	73,000	499,000	...	572,000	56	3·31
Ajmere	89,000	...	5,000	94,000	5	·17
Baluchistan	68,000	...	...	68,000	...	2·52
Andaman Islands	15,000	...	1,237,000	1,252,000	98	78·25
Berar	2,711,000	...	...	2,711,000	24	·94
Total Bengal Presidency	30,157,000	18,485,000	11,303,000	59,945,000	14	·36
Madras	6,039,000	...	4,961,000	11,000,000	20	.31
Bombay	6,598,000	2,688,000	...	9,286,000	12	·49
Grand total of British India	42,794,000	21,173,000	16,264,000	80,231,000	13	·36

5. *Forest Policy in India.*

In former times certain forests were carefully protected as game preserves for the pleasure of kings, princes and great nobles. These areas were of small extent when compared with the area of the country. The idea of preserving forests for the supply of timber, fuel and other forest produce, or on account of their indirect effects on climate, rainfall, the regulation of moisture, the stability of the soil on sloping ground, etc., is of modern origin, as has already been pointed out above. Under the policy of the Government of India, as developed during the last forty years, an area equal to 13 per cent. of the total area of the country has been placed under the management of the Forest Department; the question then arises, whether the Government of India has gone too far in this matter, or not far enough, and if the latter, what further steps should be taken?

It would lead too far to discuss this question here in all its details, but the main issues may be shortly touched upon. It is necessary, then, to consider chiefly the following points:—

(*a.*) Forests in relation to Climate and Rainfall.
(*b.*) The Regulation of Moisture.
(*c.*) Forest Produce required by the Country.

a. Forests in Relation to Climate and Rainfall.

The relation between forests and the climate and rainfall of India is of a very peculiar nature. On the one hand, a covering of forest vegetation reduces the temperature of the air and soil, increases the relative humidity, and tends to increase precipitation, while on the other hand the exceptionally high temperature which prevails in spring and early summer over the centre of the Indian peninsula is one of the main agencies which bring about the summer monsoon rains, on which the welfare of India depends. In other words, extensive afforestation might increase the quantity of locally formed clouds and produce local precipitations, but it might also weaken the force of the south-west monsoon winds and consequently the accompanying rainfall. It is perhaps difficult to say what the ultimate effect of a general afforestation might be, but it may reasonably be assumed that the effects of forests, however extensive, are not likely to produce a quantity of rain, which would make up for any weakening of the south-west monsoon. As a matter of fact, however, more than half the area of Madras, Bombay, the North-Western Provinces and Bengal is under cultiva-

tion, and a considerable additional area has been appropriated as grazing grounds, so that not more than one-fourth could remain under forest, an area, which may be sufficient to moderate the temperature locally, but which is not likely to interfere with the advent of the annual south-west monsoon. The latter must for ever be the main source of moisture in India. Apart, however, from these theoretical speculations, it has yet to be proved, whether afforestation in low or level lands affects the rainfall at all. The extensive observations made of late years in Europe, have not yet led to any decided results, and those carried out in India have not extended over a sufficient number of years to permit of any final conclusions.

On the whole there can be no doubt that, even under the most favourable circumstances, the climate and rainfall of the Indian plains are subject to other influences, compared with which the effect of a limited forest area must always be very small. At the same time it need scarcely be mentioned how gratefully the shade of forests will be accepted by man and beast in a country as hot as India, and in many cases forests act beneficially as shelter belts to adjoining cultivated lands.

b. Regulation of Moisture.

It will be easily understood that the regulation and proper husbanding of the available moisture must be of great importance. As far as forest vegetation assists in this, the subject must be considered chiefly from two points of view :—

(1.) In respect of the evaporation of moisture.

(2.) In respect of the mechanical action of forests.

The difference in evaporation from an area exposed to the full effects of the sun and another sheltered by a dense growth of forest vegetation must be much greater in a tropical country like India, than it has been proved to be in a temperate climate. Hence the presence of forests must act highly beneficially wherever the rainfall is limited, or unfavourably distributed over the seasons of the year; in other words, especially in the Indus and West-Gangetic plain, the drier parts of the Peninsula and in Upper Burma.

There is, however, a second way in which forest vegetation acts most favourably, namely, as a help towards successful irrigation. Of the 199,500,000 acres which are cultivated annually in India, no less than 30,000,000 acres are artificially watered either by canals, or from wells, lakes, and tanks. Some of the canals are fed with water derived from the enormous snow fields of the Himalayas, and the rest with water which comes from other sources. Accordingly the irrigated area may be classified as follows:—

Area irrigated from	snow-fed canals	3,000,000	acres.
,, ,, ,,	other canals .	5,000,000	,,
,, ,, ,,	wells . .	13,000,000	,,
,, ,, ,,	other sources .	9,000,000	,,
	Total . . .	30,000,000	,,

Only 3,000,000 acres, equal to 10 per cent. of the total irrigated area, rely directly on the melted snow of the Himalayas. Of the 13 million acres irrigated by well-water, 10½ millions are situated in the Indo-Gangetic plain. The wells in this plain may be said to tap great underground reservoirs underlying the plain. Part of

this water may come from melted snow, but the greater portion consists no doubt of the rain water which sinks into the ground.

The remaining 16½ millions of acres derive their water from the rain which falls on the heated surface of low lands and moderately high hills. The larger the proportion of the catchment areas, whence this irrigation water comes, which is shaded by forest vegetation, the more favourable and sustained will be the supply of water. Here then is a mission which forestry in India has to fulfil.

The mechanical action of forest vegetation on sloping ground, also, is not without importance in India. There is sufficient evidence to show what careless or injudicious clearing of forests may do. Anyone who has ever stood on the hills behind Hushiarpur in the Punjab, and looked down upon the plain stretching out towards the south-west, has carried away an impression which he is not likely to forget. In that part the Siwalik range consists of an exceedingly friable rock, looking almost like sand baked together. Formerly, the range was covered with a growth of forest vegetation, but a number of years ago cattle owners settled in it, and under the combined attacks of man, cows, sheep and goats the natural growth disappeared, while the tread of the beasts tended to loosen the soil. The annual monsoon rains, though not heavy, soon commenced a process of erosion and of carrying away the surface soil. Gradually small, and then large ravines and torrents were formed, which have torn the hill range into the most fantastic shapes, while the *débris* has been carried into the plains, forming fan-shaped accumulations of sand, which, commencing at the places where the

torrents emerge into the plain, reach for miles into the plain, and have already covered and rendered sterile extensive areas of formerly fertile fields. Indeed, one of these currents or drifts of sand has actually carried away a portion of the town of Hushiarpur. The evil has by no means reached its maximum extent, and if curative measures are not adopted at an early date, the progress of transporting the hill range into the plain will go on, until the greater part of the fertile plain stretching away from its foot has been rendered sterile. To cure the evil, it is necessary to stop grazing, at any rate that of goats and sheep, so as to allow the hills to re-clothe themselves with a covering of plants, shrubs and trees, and to help by artificial sowing and planting wherever required.

Although the case of the Hushiarpur Chos, as they are called, is the worst of its kind in India, there are other instances which prove that afforestation is essential on hill sides, wherever the rock is friable and liable to be carried away by the continued action of water. It would, however, be a mistake to assume that every hill slope requires to be under forest. Over considerable areas the rock is firm, and capable of holding its own without the steadying help of a growth of forest vegetation.

c. Forest Produce required in India.

Although India has an extensive seaboard, along which forest produce can be landed, it does not derive so much benefit from this fact as might be assumed at first sight, because it is such a vast country. The distance

* See Baden Powell's pamphlet.

between the seashore and the places of consumption in the interior of the country amounts frequently to many hundred miles; railways are not as common as they are in England, and forest produce is a bulky article; hence only the coast districts would profit by the more ordinary classes of imported forest produce, even if they could be brought in sufficient quantities from other countries. Apart, however, from a certain number of railway sleepers and a limited quantity of timber, such produce from other countries is not available. By far the greater part of India must rely on the timber and fuel produced in the country.

The iron industry of India is at present very limited, so that the bulk of iron and steel is imported; hence their use is much more restricted than in England, timber being, as a rule, used in their place. Although considerable beds of coal exist in the country, they are very inconveniently situated, so that coal is at present chiefly used for industrial purposes; and certain railway lines even now use wood in the engines, owing to the high price of coal in consequence of the long haulage.

All the teeming millions of India use wood fuel in their domestic firing, and, if this is not available, dried cow dung. Their using coal is out of the question for a long period to come, even if it were available, because the ordinary Indian cultivator has neither the necessary firing arrangements, nor could he afford to pay for the coal.

For domestic firing, India requires to maintain enormous areas under wood, which will be more than doubled if the annual requirements of timber for construction, boat building, tools, agricultural implements, public works, railways, etc., are added. Judging by the

standard which applies to continental countries in Europe, it may be safely estimated that India should permanently maintain a forest area equal to half an acre per head of population, or, in a round figure, 110,000,000 acres in the British provinces, in order to secure a sufficient quantity of timber and firewood. That area would be equivalent to 18 per cent. of the total area of the British provinces.

Apart from timber and firewood, the Indian forests have to supply a great variety of other, or minor, produce, and in many instances forests must be maintained for their indirect advantages, so that the minimum forest area may perhaps be estimated at 20 per cent. of the total area.*

d. Conclusion.

History has proved that the preservation of an appropriate percentage of the area as forests cannot be left to private enterprise in India, so that forest conservancy in that country has for some time past been regarded as a duty of the State. Special forest laws have been passed under which about 7 per cent. of the total area have been brought under efficient conservancy, while another 6 per cent. receive a certain amount of protection; all these lands are Government forest estates. Interference with private forests always has met and always will meet with great difficulties, so that such interference should be restricted to cases of absolute necessity. Although it is not necessary to acquire as State forests the whole of the required 20

* Russia has 42 per cent.; Sweden 35 per cent.; Hungary, 35 per cent.; Austria proper, 33; Germany, 26 per cent.; Norway, 25 per cent.; Italy, 22 per cent.; France, 16 per cent.

per cent. of the total area, it seems highly desirable, that at least half that area, or say 60,000,000 acres, should be constituted permanent forest estates and managed in a systematic manner. It rests with the Government of India to do this, by increasing the area of the already constituted forest reserves from 43 to 60 millions of acres, an area which is less than one-half of the total area of forests and waste lands, which is still the property of Government.

In carrying out such a policy special attempts should be made to raise the area of permanent State forests in the provinces, where the percentage is as yet small, more especially in the Punjab, North-Western Provinces, Burma, Madras and Bengal. In most of these provinces, the necessary areas are available. Owing to the permanent settlement in Bengal it will not be possible to create a sufficient area of State forests in that province, except by acquiring additional lands.

So far the Government of India has good reason to be satisfied with the financial results of its forest administration. The net revenue, after meeting all expenses of the Department, has been as follows since 1864, the year in which the Department was first established as a general State Department:

	Rs.x.
1864 to 69, average annual net revenue	=139,971.
1869 to 73 ,, ,, ,, ,,	=150,349.
1873 to 77 ,, ,, ,, ,,	=218,116.
1877 to 81 ,, ,, ,, ,,	=223,536.
1881 to 85 ,, ,, ,, ,,	=360,276.
1885 to 89 ,, ,, ,, ,,	=450,932.
1889 to 93 ,, ,, ,, ,,	=708,900.
1893 to 94 ,, ,, ,, ,,	=837,232.

The annual net revenue during the year 1893—94 was six times that of the period 1864—69. There can be little doubt, that 25 years hence the net surplus will be at least double the present amount, if the Government of India perseveres in its forest policy as developed in the past. Indeed it would not be going too far to say, that the increasing forest revenue bids fair to become a substantial set-off against the expected loss of the Opium revenue, a loss which may occur any day.

This is the legacy left to the Treasury of the Indian Empire by the men who carried out its forest policy during the last 40 years. Unfortunately re-action seems still liable to set in from time to time, brought about by attempts to sacrifice sound forest conservancy to the temporary interests of the agricultural classes. Only two years ago a retrograde movement seemed to have set in, which, if it had been persevered with, might have destroyed the splendid results which had been attained in the past. Sounder counsels fortunately prevailed soon afterwards, so that no lasting harm seems to have been done. When forestry in Britain has become an essential part of the industry based upon the soil, those who go out from time to time to govern India will be more fully impressed by its importance, and will bring to their several spheres of action a sympathetic understanding of the importance of forest conservation; this will go a long way towards preventing a policy that might otherwise threaten to interfere with continued and well considered action, and a healthy progress of forest management in India.

PART IV.

THE FOUNDATIONS OF SYLVICULTURE.

INTRODUCTION.

SYLVICULTURE means the culture of forests, that is to say, all measures connected with the formation, preservation and treatment of forests. In practice, however, the word forestry is used to express and comprise all this, while by sylviculture is understood the formation, regeneration and tending of forests, or woods, until they become ripe for the axe. Sylviculture, in the latter sense, teaches how a forest, or wood, can be produced, so as to realize in the most advantageous manner the object of the proprietor.

The object for which a particular forest is maintained depends on the will and pleasure of the owner, in so far as his freedom of action is not limited by rights of third persons, or by legal enactments. The object itself can be one of many, and of these the following may be mentioned by way of illustration :—

(1.) To yield produce of a definite description, for instance, trees and shrubs of special beauty, or trees giving a certain kind of timber, or other produce fit for particular purposes.

(2.) To produce the greatest possible quantity of wood, or other produce, per acre and year.

(3.) To produce the highest possible money return per acre and year.

(4.) To produce the highest possible interest on the invested capital.

(5.) To produce certain indirect effects; for instance, to influence the climate, to regulate the drainage of the country, to prevent landslips, avalanches, etc.

In each of these and other cases, the particular species of tree to be grown and the method of treatment are likely to differ, and it is the business of the forester to select those species and methods which realize the object of management most fully and in the most economic manner. More especially, the forester must always consider what effect the species and the selected method of treatment are likely to have on the property, and he must remember that any exceptional strain put upon the soil for more than a limited period, in order to realize an exceptional effect, must be followed by a corresponding period of relaxation. Unless this is secured, the soil, in the majority of cases, will deteriorate, and it may ultimately become absolutely sterile. Such an exceptional strain may suit the special requirements of a particular owner, but is not in the interest of the general community. Political Economy teaches, that the correct mode of procedure points to the careful preservation of the productive powers (or factors) of any given locality, so as to render possible the production of the same effect, or even an increased one, regularly and indefinitely.

Experience has shown that in forestry the safest method of preserving the productive powers of a locality consists in maintaining uninterruptedly a crop of forest vegetation on the area. The more frequently and the longer the ground is uncovered and exposed to the full effects of sun and air currents, the more, in the majority of cases, is the productive power liable to be reduced. The

justification of this theory will be found in the first chapter of this part of the Manual.

The natural forest vegetation of the various parts of the earth consists of a large number of species of trees and shrubs, each of which has its peculiar mode of growth, and thrives best under certain conditions. Only certain species of trees possess the faculty of forming by themselves healthy and flourishing woods, while others will only obtain perfection if they are mixed with the former. Species are called *ruling*, or *dependent*, according to whether they belong to the first or second category. Owing to the great number of species and the ever-changing conditions in different parts of the earth, it would be altogether impracticable to deal with all in a book which has for its object to teach the theory of sylviculture. The general principles of sylviculture hold good all over the world, but the illustrations must be taken from a limited area. In the present volume they will be taken from the timber trees ordinarily growing in Western Europe on the 50th degree of northern latitude, and the countries immediately to the north and south of it. If the more important species of timber trees growing in that region are classified in accordance with what has been said above, the following lists are obtained :—

Ruling Species.

Decidedly ruling.—Spruce, silver fir, beech, Scotch pine.

Conditionally ruling.—Hornbeam, oaks, larch, common alder, birch, willows.

Dependent Species.

Of these may be mentioned: Ash, Norway maple, sycamore, sweet chestnut, aspen, elm, lime, white alder, Weymouth pine, Austrian pine, Cembran pine, mountain pine, etc.

Although the biological characteristics of these and other species have been carefully studied for many years past, the subject has been by no means exhausted, because the factors which affect the growth of trees vary constantly, and moreover some of these factors are as yet imperfectly understood. The experience already gathered will be found in the succeeding chapters. It is that experience which must guide the forester in the selection of species for a particular locality, and of the subsequent method of treatment.

The subjects which claim attention will be dealt with in the following four chapters:—

CHAPTER I.—LOCALITY IN RELATION TO FOREST VEGETATION.

„ II.—THE DEVELOPMENT OF FOREST TREES.

„ III.—CHARACTER AND COMPOSITION OF WOODS.

„ IV.—THE SYLVICULTURAL SYSTEMS.

These are matters which govern all forest operations, not only the formation, regeneration, and tending of woods, but also the determination of the yield, the preparation of working plans, and the ultimate utilization of the forest produce; hence it seems justifiable to

place them together in a separate part, instead of in the next volume, which deals with the formation, regeneration, and tending of woods, or Practical Sylviculture.

The works which were chiefly used in the preparation of this part are :—

(1.) Hartig, "Lehrbuch für Förster," first volume.
(2.) Heyer, "Der Waldbau."
(3.) Gayer, "Der Waldbau."
(4.) Hess, "Encyklopädie der Forstwissenschaft."

CHAPTER I.

LOCALITY IN RELATION TO FOREST VEGETATION.

When a plant germinates on the surface of the earth, it sends its roots into the soil, and its stem into the air. The soil, assisted by the subsoil, provides to the plant the means of stability and nourishment; the atmosphere overlying the soil furnishes certain nourishing substances, heat, light, and moisture. Hence soil, including subsoil, and atmosphere are the media which act upon forest vegetation, and they together are in sylviculture called the "*locality*." The active agencies, or factors, of the locality depend on the nature of the *soil and the climate*, the latter being governed by the situation. The sum total of these factors represents the quality or yield capacity of the locality. The forester requires to be well acquainted with the manner in which soil and climate act on forest vegetation, in order to decide in each case which species and method of treatment are best adapted, under a given set of conditions, to yield the most favourable results. The detailed consideration of the laws which govern this branch of forestry finds a place in the auxiliary sciences, such as Physics, Chemistry, Meteorology, Mineralogy, and Geology. The subject is, however, of such importance, that an enumeration of the more important points appears justified, before proceeding to explain their effect on forest vegetation.

Accordingly this chapter has been divided into the following sections :—

Section I.—The Atmosphere.
„ II.—Climate.
„ III.—Soil.
„ IV.—Effect of the Soil on Forest Vegetation.
„ V.—Effect of Forest Vegetation on the Locality.
„ VI.—Assessment of the Quality of the Locality.

Section I.—The Atmosphere.

The earth is surrounded by gaseous bodies, which move with it, and collectively are termed the atmosphere. Owing to the weight of its component parts, the atmosphere is densest close to the surface of the earth, and becomes thinner with increasing distance from the earth passing gradually into space.

The atmosphere consists essentially of the following substances :—

(1.) Atmospheric air.
(2.) Carbon dioxide.
(3.) Water, in various conditions.
(4.) Solid bodies.
(5.) Ammonia and Nitric Acid.

1. *Atmospheric Air.*

The atmospheric air consists of a mechanical mixture of 21 parts of oxygen with 79 parts of nitrogen and argon. No chemical process is required to separate

oxygen from nitrogen; as a matter of fact, all porous bodies possess the faculty of taking oxygen from the atmosphere, without entering into a chemical combination with it. Amongst such bodies are the soil and the leaves of plants. Until a comparatively late date it was believed that plants could not take nitrogen direct from the air. It has now been proved that certain plants, including various forest trees, can do this, and further investigation will doubtlessly lead to additional discoveries in this respect. Argon has quite lately been discovered, and it would be beyond the scope of this book to discuss it further.

Although the leaves of plants take up oxygen, they exhale greater quantities of it under the effect of light; the latter is the result of the decomposition of carbon dioxide by the leaves, which retain the carbon and surrender the oxygen. Thus, plants are powerful agents in the production of oxygen.

The action of the air in the soil is chiefly two-fold; it causes the evaporation of moisture, and the decomposition of organic matter. The air which penetrates into the fissures and interstices of the soil becomes laden with vapour and carbon dioxide; it is then forced out of the soil by every rise of temperature during the day, and replaced by fresh air during the cooling of the night. The extent of this change of air depends on the degree of porosity of the soil and the daily range of temperature; the greater these are, the more rapidly will moisture and organic matter (humus) disappear. The daily range of temperature is seriously affected by the degree of protection which the soil receives from forest vegetation; it is greatest in fully exposed soils, and

smallest in soils which rest under the shelter of a crowded crop of trees, especially if the foliage offers lateral as well as vertical shelter against sun and air currents. In the latter case the humus is generally carefully preserved, in the former it disappears rapidly.

2. *Carbon Dioxide.*

The atmosphere contains up to 0·0004 of its volume of carbon dioxide, which is received from a variety of sources, as combustion or decomposition of plants, the breathing of animals, volcanoes, spring water issuing from the interior of the earth, combustion of coal and lignite, from various minerals, as for instance calcium carbonate. Of these, the first is by far the most important source of supply.

Plants, except those of certain orders, take the carbon dioxide which they require through their leaves from the atmosphere. Subsequently, when they die and are decomposed, their carbon is converted back into carbon dioxide, and returned to the atmosphere; hence plants form an important link in the movement of carbon dioxide.

3. *Moisture.*

The atmosphere is the medium through which the dry land receives the greater part of the necessary moisture. Sheets of water (the sea, lakes, rivers, etc.) and moist bodies evaporate moisture which, as vapour, rises in the atmosphere, until it is again condensed into water.. It either settles as dew on cool objects, or falls as rain, snow, or hail from the cloud region to the ground.

Plants being moist bodies, take part in the circulation of moisture; they receive it from the soil through the roots, and evaporate it through the leaves.

In this eternal circular motion of moisture, several points are of special interest to the forester. In order to convert water into vapour, heat is required; the consequence is, that evaporating bodies become drier and cooler, and reduce the temperature of the surrounding layers of air in their effort to replace the expended heat. It follows that the rate of evaporation is, amongst other influences, governed by the temperature, in other words by the climate. There is, however, another reason why the rate of evaporation depends on the temperature:—The maximum of vapour which saturated air can hold rises at a more rapid rate than the increase in temperature. If, for instance, one cubic foot of air is saturated with vapour when it contains ·15 grams of water at freezing point (32° F.), it can hold ·28 grams at a temperature of 54½ degrees, and ·64 grams at 77 degrees. It follows that air of a high temperature can hold more vapour than at a low temperature, and yet the relative humidity may be smaller in the former case. Hence evaporation is more rapid in summer than in winter; it is generally also greater during the day than at night.

4. *Solid Bodies.*

The atmosphere always contains a certain amount of organic and inorganic solid bodies, which are kept in suspension in consequence of their minute size and lightness. When vapour is condensed and falls to the

ground as rain, snow, or hail, it carries with it a certain quantity of these solid bodies, which differs according to locality; the mineral part of these deposits is not inconsiderable compared with that which is required annually for the production of timber on a fully stocked area. Amongst the substances thus brought to the ground are calcium carbonate, magnesium carbonate, sodium chloride, calcium sulphate, ferric oxide, alumina, silica, organic nitrogenous matter, etc. Direct analysis has shown that upwards of 300 lb. of these substances have been deposited on an acre of land in one year, a quantity more than sufficient to provide for that contained in a heavy increment of wood laid on during the same period. In other cases, observations have shown that the quantities deposited are considerably less than 300 lb. per acre.

5. *Ammonia and Nitric Acid.*

Limited amounts of these important substances are contained in the atmosphere; they supply nitrogen to forest plants in considerable quantities, especially for the formation of seeds.

A certain quantity of ammonia and nitric acid is contained in the annual rainfall, but is not sufficient to meet all the requirements of a forest crop.

Section II.—Climate.

By climate is understood the different local peculiarities of the atmosphere in respect of temperature, degree of clearness, moisture and rest or motion. It

has already been indicated, that the climate of a locality depends on its situation.

The climate of a locality is of greater influence upon the life and growth of plants than the degree of fertility of the soil; hence it demands the forester's special attention. Generally speaking, the climate of a locality depends on:—

(1.) Latitude and longitude, or geographical position.
(2.) Elevation above the level of the sea.
(3.) Aspect and gradient.
(4.) Shape of the surface and condition of surroundings.

Each of these affects the heat, light and humidity of a locality, which are the agencies determining the commencement and course of the annual phenomena of vegetation.

1. *Heat.*

Heat affects plant life in various ways. In the first place, it is necessary for transpiration by the plants and evaporation from the surface of the earth; and secondly, it governs the movement of the air, which produces a thorough mixture of its different ingredients, as well as that of warm and cold, dry and moist, clear and hazy air.

As plants have in general no internal source of heat, that required for transpiration must be supplied to them by the atmosphere, either directly or through the soil. If these are themselves deficient in heat, transpiration must cease as soon as the plant has expended the store of heat which it contains. The latter, however, frequently does not take place until serious damage has been done

to the plant, in other words, the temperature of the plant may be so far reduced that the freezing point is reached, although the temperature of the surrounding air is still several degrees above that point.

The only important source of atmospheric heat is the sun; hence the temperature of a locality depends in the first place on its *latitude.* The mean annual temperature decreases with the distance from the equator, because the sun's rays strike the earth more obliquely in proceeding north or south from the equator towards the poles. The climate thus produced is frequently called the *geographical* or *solar climate.* It exists nowhere on the earth, because it is modified and converted into the *physical* or *local climate* by a series of influences, amongst which the following deserve attention :—

a. Elevation above the Level of the Sea.

The temperature falls with elevation above the sea. In the Alps the fall is one degree for every 300 to 400 feet of elevation; it is about 900 times as rapid as the fall caused by increasing latitude. The effect of elevation upon temperature is subject to modifications. High plateaux of considerable extent show a milder climate than that calculated for their elevation, because the sun's rays are more intense than at the level of the sea. On the other hand, wind currents exercise a considerable effect, so that isolated peaks have, as a rule, a comparatively rough climate.

Cold air, owing to its weight, glides down slopes and may become stationary in valleys and low land generally, producing locally and temporarily a lower temperature than that which corresponds to the elevation of the locality.

b. Presence of Extensive Sheets of Water.

Owing to a difference of temperature, and the consequent exchange of air between dry land and sheets of water, the latter cause the climate of the former to be more equable, the temperature being lower during the day and higher during the night. It is for this reason that the longitude of a locality, by affecting its distance from the ocean, may influence the climate.

c. Aspect and Gradient.

The angle at which the sun's rays strike the soil depends on the aspect of the locality; hence, in the northern hemisphere, aspects between south-east and south-west are the warmest, and those between north-east and north-west the coldest. The degree of the gradient further modifies this effect, which also depends on the latitude.

The aspect affects the temperature also in exposing a locality to air currents, or protecting it against them. This effect may be favourable or the reverse according to the nature of the air currents.

d. Presence or Absence of Forest Vegetation.

Localities, which are bare of vegetation, are struck by the full force of the sun's rays, causing the temperature at the surface of the soil to rise to the highest possible degree. At the same time, air currents sweep unimpeded over such localities, causing a rapid change of the atmosphere.

On localities covered with a crowded crop of forest vegetation the sun's rays strike the crowns of the trees; the heat absorbed by the air at some height above the

ground, penetrates only slowly through the leaf canopy to the layer of air below it and thence to the soil. During the night again the leaf canopy prevents, or at any rate reduces, radiation. It follows that the air in forests is cooler during the day and warmer during the night, than the air on bare localities. This effect is intensified by the fact that the foliage of the trees impedes the force of air currents.

Direct observations have established the following facts:—

(1.) The climate of wooded countries is more equable than that of open countries.

(2.) The mean temperature of soil and air in wooded countries is somewhat lower than that of soil and air in bare countries. This reduction of temperature would ordinarily act beneficially in warm southern countries, while it may become injurious in cold northern countries where the temperature is already lower than is desirable.

(3.) The greatest difference occurs in summer, next in spring, then in autumn, and it is very small in winter. It follows that in forests the commencement of vegetation in spring is retarded. This may be beneficial in preventing damage by spring frosts, limiting the formation of inferior spring wood, etc.; on the other hand it shortens the growing season, and delays the sprouting of seeds in spring.

Heat is the most powerful agency in the distribution of plants on the earth; the species change with increasing latitude, elevation and other influences which govern the temperature. This applies to forest trees as well as other plants.

Attempts have been made to ascertain the *absolute*

sum of heat required annually by the more important forest trees, which have been enumerated in the introduction of this part, but so far the data which have been obtained are not of much practical bearing upon sylviculture. Moreover, it is beyond doubt, that mean temperatures are much less important to forest trees than the extremes of temperature which occur in a particular locality, more especially during the growing season.

Something more definite is known of the *relative* heat requirements of the several species. According to Gayer this is as follows:—

It is greatest in: Common elm, sweet chestnut, pedunculate oak.

Somewhat smaller in: Austrian pine, silver fir, beech, Weymouth pine, sessile oak, lime, Scotch pine.

Less again in: Norway maple, birch, sycamore, ash, alder, hornbeam, spruce.

Least in: Larch, Cembran pine, mountain pine

The different degrees of heat requirements produce many phenomena of interest to the forester, of which the following may be mentioned:—

(1.) On the same latitude the several species, if left to natural selection, are found at different elevations. While the Cembran pine finds full development near the upper limit of tree vegetation (up to 7,000 feet in the Alps), the larch and next the spruce prefer a somewhat lower zone; lower again appear beech and silver fir and sessile oak, while the Scotch pine and pedunculate oak flourish in the low lands.

(2.) A species which prefers a certain altitude in one locality, will descend towards the level of the sea

with increasing latitude, or ascend with decreasing latitude.

(3.) At the same altitude, the more heat requiring species will seek the warmer southern aspects, and the less heat requiring species the cooler northern ones.

(4.) A species, which is naturally found on a northern aspect at a low elevation, will seek a southern aspect at a higher altitude.

It must not, however, be overlooked, that the actual distribution is affected by many other influences besides heat, and that the above theories are only of an abstract nature.

The effect of *frost* on the various species is intimately connected with their heat requirements. Trees suffer, as a rule, little from winter frosts within the region of their natural distribution, but frost which occurs during the growing season may do considerable damage; especially during spring (late frosts), immediately after the tender leaves and shoots have been put forth, and during autumn (early frosts), before the newly formed wood has had time to ripen. Many influences and circumstances contribute towards the occurrence of late and early frosts. Sometimes they are caused locally, especially in low lying or confined localities in consequence of excessive radiation or evaporation and absence of air currents; in other cases they are due to cold winds. The several species vary much in their bearing towards late and early frosts; in a general way the following classification will hold good:—

Most subject to suffer from late and early frosts are:

Ash, acacia, sweet chestnut, beech, silver fir.

Somewhat less: Oaks, Norway maple, sycamore, spruce, alder.

Least: Hornbeam, elm, birch, larch, aspen, Austrian and Scotch pine.

The degree of damage depends, apart from the severity of the frost, on the condition of the leaves and young wood, the general health and vigour of the plants and whether they have been suddenly or gradually deprived of shelter.

2. *Light.*

The earth receives light from the sun, the source whence heat is supplied. With the exception of certain forms, all plants require light to enable them to live and grow, as soon as the available reserve materials have been consumed. Without light carbon dioxide cannot be decomposed by the chlorophyll of the plants.

During the process of germination light is not required, because the embryo is developed by means of substances deposited in the seed. Similarly, the first starting of vegetation in spring can take place with a small amount of light, because it is done by means of reserve materials deposited in certain parts of the plant. As soon as these substances, both in germination and the awakening of vegetation in spring, have been consumed, light becomes absolutely necessary for the preparation of new food materials.

All trees, then, require light for their proper development, but the necessary quantity has its upper and lower limit. Not only too little but also too much light can interfere with the phenomena of growth. Between the maximum and minimum a degree exists which corre-

sponds with the most favourable development of a species, and which represents its normal light requirement. Regarding the absolute quantity of light required by the several species little is known at present, but much experience has been collected which demonstrates their relative light requirements. On the whole it is known that certain species cannot thrive unless they enjoy a large measure of light throughout life, while others will bear a certain amount of shade. Accordingly, the former species are termed *light demanding*, and the latter *shade bearing*. In a general way it may be said, that trees with a dense crown are shade bearing, and those with a thin crown light demanding, though the light requirement does not always stand exactly in inverse proportion to the density of the crown.

Attention must here be drawn to the fact, that some species, which are shade bearing, require a certain amount of shelter, or protection, during early youth; they have therefore been called "shade demanding." Such a definition is, however, misleading, as these plants require protection against heat and cold, and not against light as such. In young plants of beech and silver fir, for instance, transpiration frequently reaches such a high degree, if they are not sheltered, that they lose water more quickly than they can take it up from the soil, and consequently die. Hence they require either a thorough wetting of the soil, or shelter. In the former case more water is available, and in the latter the temperature and thereby the transpiration is reduced.

By summing up the available experience of the light

requirements of a number of species, scales have been prepared by various authors, which, though generally agreeing, differ somewhat in details. The following scale begins with the most light demanding species and finishes with the most shade bearing :—

(1.) Larch, birch.
(2.) Scotch pine, aspen, willows.
(3.) Oaks, ash, sweet chestnut, mountain pine.
(4.) Elm, common alder, Austrian pine.
(5.) White alder, *lime*, *Weymouth pine*, Norway maple, sycamore, Cembran pine, hazel.
(6.) Spruce, hornbeam.
(7.) Beech.
(8.) Silver fir.
(9.) Yew.

Lime and Weymouth pine stand in the centre of this scale; the species above them are considered light demanding, and those below shade bearing, the degree in each case depending on the distance from the centre line.

The above scale represents only general averages. In reality the degree of light requirement is subject to considerable modifications caused by the peculiarities of each locality. Generally, all species bear more shade on good fresh soil than on poor dry ground, a fact which is always indicated by the density of the crown. The Scotch pine, for instance, grown in fresh soils in countries near the sea looks quite different from the same tree seen in continental countries, and stands considerably more shade than the latter.

The length of the growing season also influences the

degree to which a tree will stand shade. A certain total quantity of light is required to complete the annual cycle of development, hence a more energetic effect of light is wanted in localities with a short growing season, such as high elevations, or high latitudes. A species which stands a certain amount of shade at the level of the sea and in a southern climate, may become highly light demanding at a considerable elevation, or in a northern climate. Again, in foggy air, under a usually covered sky, or on northern aspects, the same species stands less shade than in usually clear air, under a sunny sky, or on southern aspects. In this respect it must be remembered that the actual intensity of the light is somewhat greater in high mountains than in low lands.

The health of the trees is also of importance. Strong healthy plants with a good root system stand more shade, and for a longer period, than weak plants.

Light and shade in relation to tree growth are of the greatest importance in practical sylviculture, especially in the regeneration and tending of woods, the composition of mixed woods, etc. In each of these cases the light requirement of the species must be fully considered, or serious mistakes may be made. The most important period in this respect is early youth, because at that time several species require some shelter, either against heat or frost. If that shelter, on the other hand, is excessive the young trees may be permanently injured or even die. When a plant has stood in shade for some time, the activity of its leaves is reduced, and it takes some time, after the removal of the shelter, before the increased light produces in-

creased assimilation and visible activity, because fresh organs, fitted for the altered conditions, must be produced. In all such cases it is best to remove the cover gradually and not all at once. If the plant has stood in shade for a considerable period it may be no longer capable of developing into a tree of normal size. As long as several strong buds are found, especially near the top, this is not to be feared, but the recovery of plants with a few miserable buds may be considered as hopeless.

3. *Moisture.*

The first question for consideration is, whether moisture in the air is directly necessary or beneficial to plant life. The investigation of this problem meets with great difficulty, because it is often difficult to separate the effect of air moisture from that of soil moisture. As a matter of fact only meagre data are available as far as trees are concerned. It is known that some species, such as spruce, alder, maple, ash, and next to these, silver fir, beech and birch, thrive generally better in moist than in dry air. It is also a fact, that spruce appears naturally over extensive areas in high situations and along the sea shores of northern Europe, that is to say, in localities with a comparatively moist air, while it thrives but indifferently in continental situations with a dry air. The Scotch pine, on the other hand, appears over extensive tracts in continental dry climates, and at the same time flourishes in the moist insular climate of Great Britain.

Although further investigation is necessary to show whether trees take up moisture through their organs

above ground, the atmospheric moisture is of the highest importance, for the following two reasons :—

(*a.*) It governs the degree of transpiration from the leaves of the trees.

(*b.*) It supplies the soil with water, whence it is taken up by the roots of the trees.

Apart from the temperature, the degree of transpiration depends on the degree of saturation of the air; hence relatively dry air causes rapid transpiration, while the latter ceases as soon as the air becomes saturated. The degree of transpiration, in its turn, governs the rapidity with which fresh water laden with raw materials is taken up by the roots.

The soil receives water from the atmosphere in the shape of precipitations, as dew, rain, snow, hail, and a certain amount by means of its hygroscopic nature. The quantities differ enormously in different climates and localities, from almost nothing to over 500 inches a year. Precipitation cannot take place unless the air becomes saturated. The phenomena which favour an increase in the relative humidity, and thereby induce saturation, are active evaporation and a reduction of temperature. On the one hand, evaporation causes a reduction of temperature, and on the other a falling temperature reduces the degree of evaporation; the result is, that saturation and precipitation occur only locally.

As a general rule a low temperature means a high degree of relative humidity; hence the latter is greater in winter than in summer; greater at high elevations than in low lands; greater in the vicinity of extensive sheets of water than in continental countries; greater in forest countries than in bare tracts.

Direct observations have shown that the relative humidity of forest air is greater than that of open air, the difference amounting in Central Europe to as much as 10 per cent. during summer, and about half that amount in winter. The practical value of this fact in sylviculture is, that radiation of heat is much slower in moist than in dry air; hence the danger of late and early frosts is smaller in the former than in the latter.

4. *Air Currents.*

The atmosphere is, practically, in constant motion. The principal cause of this is the uneven heating of the earth by the sun. The heat, which becomes free on or near the surface of the earth, warms the adjoining air and causes it to rise, its place being taken by colder air from other parts of the earth. The ascending air, after cooling, sinks again in its turn. In this manner a circular motion exists between the equator and the poles. Owing to a combination of these currents with the motion of the earth, modified wind directions are produced. The prevailing wind directions on the northern hemisphere are, therefore, from the south-west and the north-east, according as to whether the original current started from the tropics or the polar region.

A second cause of wind currents, especially of storms or gales, is the sudden condensation of considerable quantities of aqueous vapour, which forces air to rush from all sides into the space of reduced pressure.

Air currents are of paramount importance to all organic life on the earth, because they produce a thorough mixture of the constituents of the atmosphere.

Without them, the land would soon lose all moisture. The motion of the atmosphere ensures a proper distribution of moisture, carbon dioxide, oxygen and nitrogen over the earth.

Air currents affect forest trees injuriously principally in two ways:

(*a.*) By unfavourably modifying the temperature and moisture of a locality.

(*b.*) By injuring, breaking, bending, or overturning them.

Dry winds frequently reduce the moisture of a locality to a dangerous degree; moist and cold winds may reduce the temperature, and thus interfere with the healthy growth of the trees. Strong winds may break the leading shoots or side branches, cause trees to assume a curved shape, or even throw single trees and whole woods to the ground.

Section III.—Soil.

It has been already stated that plants, and more especially trees, require a certain layer of soil, into which their roots penetrate, and which provides them with nourishment and the means of stability. Wherever this layer of soil is deep enough to meet the above requirements, the subsoil is only of indirect importance, but in the case of shallow soils the subsoil has, as a rule, to undertake part of the ordinary functions of the soil. Under any circumstances, the subsoil furnishes the materials from which the mineral parts of the soil are

principally derived. Hence, in speaking of the soil, the subsoil is more or less included.

1. *Origin of Soil.*

All soil is originally the result of the disintegration of the rocks of the earth, with the addition of certain organic substances. In some cases the soil now overlies the rock from which it has been derived, in others it has been carried away by violent convulsions, or the action of water and air currents, and deposited again in other places. In the former case the soil is called "*indigenous*," and in the latter "*exotic*." The most important form of the latter is alluvial soil, formed by deposits near the sea coast, in river deltas and inland by water courses and lakes, as well as by the action of air currents.

2. *Formation of Indigenous Soil.*

The formation of soil is due to a variety of agencies, which are either of a mechanical, chemical, or organic nature.

a. Mechanical Agencies.

Amongst these, heat takes the foremost place. The heating of rocks produces an unequal strain and pressure, which cause them to burst in various directions. Then, if water penetrates into the interstices and freezes, it forces the particles asunder, thus further breaking up the rock. Water is also a powerful agency, owing to its dissolving action.

b. Chemical Agencies.

When oxygen, carbon dioxide and water come into

contact with the rock, they form chemical combinations with its elements. The oxygen acts especially on the metals, forming, by the addition of water, hydrates of metallic oxides. This process, accompanied by an increase of volume, destroys the previous cohesion of the rock. Water containing carbon dioxide penetrates the rock, dissolves its various constituents and carries off lime, magnesia and potash.

c. Organic Agencies.

When mechanical and chemical action have commenced the decomposition of the rock, organic action sets in. Lichens, followed by mosses, appear on the surface of the rock, which further accelerate disintegration, by keeping the surface moist. Next, the roots of these plants penetrate into the finest fissures and assist mechanical action. In this manner a soil is gradually formed, which consists of fragments of rock and remnants of dead plants, suitable for the support of more highly organized plants, such as grasses and herbs; these are followed by shrubs and trees, which penetrate with their roots deeper and deeper into the rents and fissures of the rock, and further accelerate disintegration.

When this process has gone on for a sufficient length of time, the outer part of the earth's crust consists of a layer of varying depth, which, commencing from below, changes gradually from the solid rock into broken rock, or brash, then into smaller pieces of rock, or subsoil, and ultimately into the formed or surface soil.

At first sight it would appear, that the composition and quality of the soil depend solely on the composition of

the original rock, out of which it has been formed. This is, on closer investigation, found to be the case only to a limited extent, because, in the first place, certain important substances, such as potash, magnesia, lime, may be carried away and lost during the process of disintegration; secondly, organic substances are added; and thirdly, the fertility of the soil depends not only on its chemical composition, but also, and often chiefly so, on its physical properties. All that can be said is, that certain kinds of rock yield ordinarily a soil of a certain description, but subject to modifications, which depend on the peculiarities of each case. On the whole, the attempt to estimate the quality of a soil by its geological origin only has almost invariably failed, since the same rock may produce soils of varying chemical composition and physical properties.

3. *Composition of Soil*

Soil consists generally of the following substances :—

(A.) Mineral matter, taken from the decomposed rock, or carried to the area by water and air currents.

(B.) Organic matter, being remnants of plants and animals.

(C.) Water, partly liquid, partly in the shape of vapour.

(D.) Gases, such as air, carbon dioxide and ammonia.

A. *Mineral Substances in the Soil.*

The mineral substances form, in the majority of cases,

the greater part of the soil; they may be arranged in the following four groups:—

(*a.*) Earths.
(*b.*) Salts.
(*c.*) Acids.
(*d.*) Metals.

a. Earths.

Silica, alumina, lime, and, next to these, magnesia are the earths which occur most frequently in soils.

Silica is represented chiefly in *sands*

Silica combined with alumina forms *clay*.

Clay with sand forms *loam.*

Lime appears principally as calcium carbonate in calcareous soils, also as calcium sulphate in gypsum.

Magnesia is most frequent in dolomite, though smaller quantities are found in most other soils

b. Salts.

The most important salts are:—

Potassium carbonate (potash).
Sodium carbonate (soda).
Sodium chloride (common salt).
Carbonates, sulphates and phosphates of iron and manganese.

The quantity of salts in the soil does not, as a rule, exceed one-half per cent., and rarely one per cent. Larger quantities appear only in certain localities, such as salt plains, in the vicinity of the sea coast or salt springs, and in some peaty and swampy soils.

Potassium carbonate is of importance, as forest trees

require a fair amount of it. Sodium carbonate in moderate quantities does not act unfavourably. Sodium chloride only acts favourably if present in small quantities. Salts of iron often act injuriously.

c. Acids.

Carbon dioxide and humic acid are the two free acids which generally appear in soils. Other free acids, if they appear at all, do so only temporarily, until they enter into combination with a base.

d. Metals.

Of metals, only iron is of importance in sylviculture. It appears as ferrous oxide and as ferric oxide. The former is believed to be injurious to plant life. Ferric oxide may be mixed with soils, and unless the quantity exceeds 10 per cent., it does not act injuriously; on the contrary, most fertile soils contain a certain quantity of it.

B. *Organic Matter, or Humus.*

By humus is understood in sylviculture all organic matter which, in contact with the soil, is gradually decomposed, and forms in mixture with the upper layer of mineral substances the mould or black earth of the forest. The sources of humus are the annual fall of leaves and twigs (or even whole trees) and dead plants.

The continuous decomposition of humus furnishes several important products. In the first place the soil receives all the mineral matter contained in the humus (ashes); secondly, a large quantity of carbon dioxide is

produced which accelerates the decomposition of the mineral part of the soil. Finally, humic acid renders many important substances, such as potash, magnesia, lime, etc., soluble in water, so that they become available for the plant.

There are, however, different kinds of humus:— *Mild humus*, or *forest humus* is formed, if air and water act in proper proportion upon fallen leaves, moss, etc. *Dry mould* is formed by the action of an excessive supply of air, or rather absence of moisture, on certain plants, such as heather. *Acid humus* is the result of decomposition, if there is in the soil an excess of moisture and a deficiency of air. Only mild forest humus acts altogether favourably upon forest vegetation.

C. *Water.*

Water is the most important component part of the soil, as plant life is impossible without a certain quantity of moisture. It affects vegetation principally in the following manner:—

(*a.*) It assists in the decomposition of the rocks.

(*b.*) It assists in the formation of humus, and regulates both the admission of air into the soil and its temperature.

(*c.*) It is an important agent in the process of nourishing and shaping the plant. More especially it carries all mineral substances from the soil, through the roots, into the plant.

However favourably a certain degree of moisture in the soil may act, an excess of water is always injurious;

it reduces the activity of the soil (by driving out air), lowers the temperature, increases danger from frost, and is liable to render the soil acid.

The soil receives water from one or more of the following sources :—

(1.) From the atmosphere, as dew, rain, snow, hail, or as vapour condensed by the hygroscopic action of the soil.

(2.) From ground water resting in the subsoil.

(3.) From inundations, whether natural or artificial.

Water derived from the atmosphere acts most favourably, provided the supply is suitably distributed over the different seasons of the year, and the soil is capable of retaining moisture sufficiently long during dry weather. Where these conditions are wanting, ground water is likely to act more favourably, because it produces a more even degree of moisture in the upper layers of the soil. Natural inundation water is, in many cases, objectionable, because it renders the soil too wet at one time, and too dry at others. Artificial inundation, or irrigation, produces very favourable results, but it is generally expensive.

D. *Gases.*

The gases, such as air, carbon dioxide and ammonia, have been dealt with in section I. of this chapter. It is only necessary to add, that the amount of air in the soil varies within wide limits, and that the amount of carbon dioxide depends on the quantity of organic matter in the soil, and the rate at which its decomposition proceeds.

4. *Physical Properties of the Soil.*

The principal physical properties of importance in sylviculture are the following :—

a. Consistency,

Or binding power, the cohesion between the different particles of the soil. It depends on the chemical composition of the different parts, the degree of division, and the quantity of moisture in the soil. Generally, it is greatest in clay and smallest in sand.

b. Shrinking,

Or the reduction of the volume of the soil under the process of drying. It causes cracks in the soil, followed by the exposure of the roots. Heavy soils crack more than light soils.

c. Capacity to hold Water.

It is generally proportional to the percentage of fine earth and humus in the soil.

d. Hygroscopicity,

Or the capacity of the soil to attract and condense aqueous vapour from the atmosphere. It depends on the degree of division of the particles, and on the temperature. The finer the division, the greater the hygroscopicity; more vapour is condensed at a low than at a high temperature. Soils rich in humus show the greatest hygroscopicity, next clay, then loam, then lime soils, and it is smallest in sand.

e. Tenacity in retaining Moisture,

Is greatest in clay soils, moderate in calcareous soils; sand loses moisture most quickly.

f. Permeability,

Or the capacity to let water pass through is greatest in sands, especially if of a coarse grain, and smallest in clay. Humus soil approaches clay, while calcareous soils and loam stand about half way between the two extremes. Stiff clays are liable to be altogether impermeable; in many cases the clay of a mixed soil is gradually carried into the subsoil, where it forms an impermeable layer.

g. The Power to retain Salts dissolved in Water,

Depends on the proportion of fine earth in the soil.

h. The Capacity to become Heated,

Is greatest in sands, and smallest in clay. Calcareous soils approach sand; loam approaches clay. Sand and calcareous soils are generally hot soils, while clay is a cold soil.

Depth intensifies the effect of the various physical properties. A depth of 4 feet may be considered as sufficient for any of the species enumerated in the Introduction, and many can do with considerably less. Where a sufficient depth of soil is not available, the direct assistance of the subsoil is called in, especially its degree of permeability. The depth depends chiefly upon the nature of the rock and soil, the stratification of the rock, the situation, and the general shape of the surface of the ground. The nature of the rock governs

the rate at which it is disintegrated, and the rock may be more or less permeable. An impermeable subsoil is all the more injurious the nearer it is to the surface, because it makes the surface soil too wet and cold at one time, and too dry and hot at others, apart from the fact that the roots may not find sufficient room for spreading, or that the stability of trees may be endangered.

A vertical stratification and a much crumpled state of the rock act most favourably upon the movement of water in the soil and the penetration of the roots; a horizontal stratification, if unaccompanied by crumpling, is generally the least favourable form. Low lands have ordinarily deeper soils than high lands. On steep slopes the soil is liable to be washed away, while it is collected in depressions.

All physical properties are of special importance through their action upon moisture. In this respect the chemical composition of the soil is of less importance than the degree of division of the particles, whether the latter are fine or coarse grained. It is for this reason that sand and clay represent, ordinarily, the extremes. If sand were as finely divided as clay, it would show the same bearing towards moisture as the latter.

5. *Classification of Soils.*

For the purposes of sylviculture, soils may be classified either according to their chemical composition or according to one or other of their physical properties.

a. Classification according to Chemical Composition.

It is, of course, out of the question to attempt a classification according to all component substances, nor

is it necessary, because the importance of the four substances, sand, clay, lime and humus, outweighs that of all other substances so much, that the latter need not be taken into account in this place.

The subjoined table gives the composition of the ten principal classes of soils (according to Church):—

Name of Soil.	Percentage of:			
	Clay.	Calcium Carbonate.	Sand.	Organic Matter.
1. Loams or Free Soil . .	20—30	5—10	50—70	2—5
2. Clays	over 40	under 5	under 50	2—5
3. Clay-sands . . .	,, 30	,, 5	50—70	2—5
4. Marls	,, 30	5—10	under 50	2—5
5. Peaty Clay . . .	,, 30	under 5	,, 50	over 5
6. Sands	under 10	,, 5	over 80	2—5
7. Calcareous Sands . .	,, 10	5—10	,, 70	2—5
8. Peaty Sands . . .	,, 10	under 5	,, 70	over 5
9. Calcareous . . .	,, 10	over 10	50—70	2—5
10. Peats	,, 10	under 5	under 50	over 35

Note.—Lime improves 2, 3, 5 and 8.
Draining improves 2, 4, 5 and 10.
Irrigation ,, 6 and 7.

Soils of subordinate importance are:—

Dolomite, a chalky loam with much magnesium carbonate.

Gypsum, a soil which is rich in calcium sulphate.

Salt soil, which contains an excessive percentage of salts, especially sodium chloride.

Ferruginous soil, which contains an excessive proportion of ferric oxide.

According to the preponderance of one or other of the principal ingredients, numerous subdivisions have been made, such as sandy, or marly clays; loamy sand, sandy loam, marly sand, sandy marl, etc.

Clay, loam and calcareous soils are as a rule minerally strong soils, while sandy soils are less

strong. Humus soil may be mild, dry, or sour humus soil; the former acts very favourably upon tree growth, the two latter unfavourably.

Soils may also be classified according to the rapidity with which the humus is decomposed, as:—

Very active soils: Such as dry porous sand and calcareous soils, in which the decomposition of humus is excessively quick.

Active soils: Such as moderately moist loamy sand, sandy loam, loamy marl, in which the decomposition of humus proceeds at a rate favourable for growth, without actually exhausting the supply of organic matter.

Moderately active soils: Such as stiff clay, wet soil, heather soil, where the decomposition is too slow for a healthy development of most plants.

Inactive soils: Such as peat soil, shifting sand, etc., in which, either from excess of moisture or absence of humus and rest, little or no decomposition takes place.

b. Classification according to Physical Properties.

Of the various physical properties the degrees of consistency and of moisture are of special importance in sylviculture. According to consistency, soils may be classified in the following manner:—

Light soils: All soils which contain much coarse-grained sand or much humus.

Loose soils: Such as peat and moor soils, which are elastic and swell during rainy weather; they are also much lifted by frost.

Binding soils: Soils of moderate cohesion, such as fine grained loamy sands, coarser grained sandy loams, calcareous soils, especially marl.

Heavy soils: Such as fine grained loam, clay with coarse sand.

Stiff soils: Such as clay with a limited quantity of fine grained sand.

In classifying soils according to the degree of moisture, a distinction must be made between the average degree of moisture, and the condition of the soil during the growing season, as set forth in the following arrangement:—

Wet soil: Water flows from it without the application of pressure.—Even in summer water runs off in drops on the application of pressure.

Moist soil: On pressure being applied, water falls in drops.—During summer the soil does not become dry beyond one inch below the surface.

Fresh soil: Leaves traces of moisture on the palm of the hand on being pressed.—During summer it does not become dry beyond six inches below the surface.

Dry soil: Has lost the dark colour due to the presence of moisture, but does not fall to dust on being broken.—In summer it becomes dry to a depth of 12 inches within a week after a good soaking rain.

Arid soil: Falls to dust on being broken.—In summer it dries up to a depth of more than 12 inches within a few days after a good soaking rain.

Section IV.—Effect of the Soil upon Forest Vegetation.

In estimating the effect which differently constituted soils have upon forest vegetation, and more especially upon tree growth, the forester is guided by the demands made by the trees upon the soil. Ordinarily the soil should provide the tree with:—

(*a.*) Stability.
(*b.*) Space for a suitable spreading of the root system.
(*c.*) Moisture, in suitable quantities at all times.
(*d.*) Nourishing substances, in sufficient quantities and in a condition suitable for absorption by the roots.

Any soil which meets these requirements is fertile for sylvicultural purposes, and experience has shown, that fertile forest soil must possess the following properties:—

(1.) A sufficient depth.
(2.) A suitable degree of porosity.
(3.) A suitable degree of moisture.
(4.) A suitable chemical composition.

1. *Sufficient Depth.*

The depth is measured by the thickness of the layer of soil, and of that portion of the subsoil, which can be penetrated by the roots. In due proportion to depth are the space available for the root system, the store of nourishing substances, the stability of the trees, and the state of moisture in the soil.

The root system differs considerably in the several species; some develop a tap root, which is maintained

for a longer or shorter period, such as oak, elm, Scotch pine, silver fir, maple, sycamore, ash, lime, larch; others have strong side roots, which send down deep going rootlets, such as alder; others again go to a moderate depth, as beech, hornbeam, aspen and birch; finally some spread altogether near the surface, such as spruce. The nature, composition and degree of moisture of the soil modify the root system to some extent, which in young trees frequently differs from that in older trees.

On the whole, certain species thrive well only in deep soil, while others can subsist in shallow soil, though they prefer the former. The best indicator of the depth of soil is the height growth. A sufficient depth produces full height growth; with deficiency of depth the height growth falls off.

Hess * classifies the trees as follows, in respect of their demands for depth of soil :—

Species which are satisfied with shallow soils: Spruce, mountain pine, birch, aspen, mountain ash.

Species which require moderate depth: Austrian pine, Weymouth pine, beech, hornbeam, black poplar, tree willows, alder, horse chestnut.

Species which require greater depth: Scotch pine, Cembran pine, elms, Norway maple, sycamore, white poplar.

Species which require greatest depth: Silver fir, larch, ash, lime, sweet chestnut, and especially oaks.

At the same time, the roots of these species go rarely to

* Encyklopädie and Methodologie der Forstwissenschaft, by Dr. Richard Hess, 1888.

a depth of 4 feet below the surface, unless they do not find sufficient moisture in the upper layers of the soil, a case occurring in countries with a long dry season.

2. *A suitable degree of Porosity.*

Neither too firm nor too loose soils are favourable for tree growth. Too firm soils make the penetration of the roots difficult, if not altogether impossible, prevent the admission of the necessary air, interfere with the movement of water, and incline towards swampiness, accompanied by increased danger from frost, and by strong shrinking and cracking in summer. Too loose soils endanger the stability of the trees, are liable to be carried away by water or wind, suffer from too rapid drying and too rapid decomposition of the humus, and the plants growing in it are subject to frost lifting. The best soils are of middling consistency, such as loam and calcareous soils with a good layer of humus.

3. *A suitable degree of Moisture.*

By a suitable degree of moisture is here understood that degree which corresponds to the natural requirement of any particular species, which it is desired to grow. The more uninterruptedly that degree is maintained throughout the growing season, the more favourable the development of the tree will be.

Apart from climate and subsoil, the condition of the soil itself, its depth, porosity, the nature and proportion of its component parts, affect the degree of moisture. The forester can do much, both to preserve moisture

in the soil by excluding or reducing the agencies which dissipate it, or, if there is excess of moisture, by accelerating its consumption.

The absolute quantity of moisture required annually by each species is not yet known, but experience has shown, that a fresh soil with, as far as practicable, an even and constant degree of moisture suits most of the species enumerated above. For the rest, they may be classified as follows:

Most moisture in the soil demand: Common alder; next to this ash, most poplars and willows.

Moist soil like: Cembran pine, hornbeam, elm, lime, mountain ash, pedunculate oak.

Fresh soil like: Silver fir, spruce, larch, beech, sessile oak, Norway maple, sycamore, Weymouth pine, sweet chestnut.

On dry soil thrive: Scotch pine, Austrian pine, birch, acacia, aspen.

4. *A suitable Chemical Composition.*

Apart from water and gases, the soil consists of mineral and organic substances. These affect the development of the trees partly by providing nourishment and partly by affecting the physical properties of the soil. Woody plants take by far the greater portion of their nourishment from the air, more especially carbon, but a certain portion, including the mineral substances, is derived from the soil. Hence it is of importance to ascertain the actual quantities of such substances in the plant. The contents of mineral substances vary in different parts of the tree; thus wood taken from the

stem generally contains less than 1 per cent. of ashes (according to weight), branches and twigs about 2 per cent., bark alone 2—3 per cent., and leaves and needles from 4—6 per cent. Ebermayer* gives the following quantities of the more important substances, which an average crop takes from the soil, per acre and year :—

TABLE SHOWING THE PRINCIPAL MINERAL SUBSTANCES TAKEN ANNUALLY BY VARIOUS FIELD AND FOREST CROPS FROM AN ACRE OF LAND.

Description of Crop.	Total Quantity of Ashes.	K_2O.	CaO.	MgO.	P_2O_5.	SO_3.	SiO_2
	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
Field Crops:							
Rye, Wheat, Barley, Oats	186	28	14	9	21	4	100
Leguminous Crops, various	173	44	44	11	27	9	9
Colza	199	52	39	14	43	27	9
Clover (hay)	303	98	107	27	36	11	9
Potatoes	231	107	36	18	32	14	8
Beet	320	164	36	24	28	11	14
Meadow Hay	294	71	44	18	27	11	107
Tobacco	214	55	27	13	16	12	75
Wine	199	84	41	15	24	...	...
Average	235	78	43	17	28	11	37
Crop of Trees, wood and leaves:							
Beech, High Forest	194	13	89	15	12	4	56
Silver Fir ,,	123	16	75	10	10	4	8
Spruce ,,	138	8	62	8	7	3	45
Scotch Pine ,,	52	6	24	5	4	2	6
Average	126	11	62	10	8	3	29
Crops of Trees, wood only:							
Beech, High Forest	27	5	13	3·7	2·3	0·3	2·7
Oak ,, ,,	24	2·7	18·7	0·9	0·9	0·2	0·4
Silver Fir ,,	17	6	4	3	1·8	0·9	0·9
Spruce ,,	20	4	9	2	1·3	0·6	4
Scotch Pine ,,	13	2	8	1	0·9	0·2	0·4
Birch, High Forest	12	2	4	2	1·2	0·1	0·9
Average	19	4	9	2	1·4	0·4	1·6

The data of this table justify the following conclusions:—

(1.) The substances required by forest trees are, qualitatively, the same as those required by field crops.

(2.) Beech high forest requires for the production of leaves and wood, quantitatively, nearly as much mineral substances, as an average field crop; it requires, more

* Physiologische Chemie der Pflanzen, Volume I., page 761.

lime, but much less of the rarer substances, such as potash and phosphoric acid.

(3.) Conifers require smaller quantities, especially Scotch pine, which is satisfied with about one-fourth of those wanted by beech.

(4.) For the production of wood alone (excluding the leaves) forest trees require much smaller quantities, than field crops. Thus beech takes only one-ninth, Scotch pine about $\frac{1}{18}$th, and the six species enumerated on an average about $\frac{1}{12}$th of the quantity required by field crops. Of the rarer substances, potash and phosphoric acid, trees take, on an average, only about $\frac{1}{20}$th of the quantity necessary for field crops.

(5.) Almost any soil can furnish a sufficient quantity of mineral substances for the production of a crop of trees, provided the leaf mould (humus) is not removed, and good soils will continue to do so, even if a certain portion of the humus is taken away. If, however, the removal of litter is carried on annually and for a long period, any but really fertile soils are likely to become exhausted, just as lands, on which field crops are grown, cannot as a rule go on for ever without manuring.

(6.) Poor soils, which are not capable of producing a crop of broad leaved trees, may yet be able to yield a fair return if planted with less exacting conifers, especially Scotch pine.

The above conclusions agree with the results of practical experience. It has been found, that the quantity of wood production is not directly proportionate to the quantity of mineral nourishing substances in the soil. Again, woods thrive equally well on soils

of the most different geological origin, while great differences exist in the development of one and the same species if grown on soils of the same geological origin. These phenomena are explained by the great importance of the physical properties of the soil, depth, porosity and a proper degree of moisture. To ensure a favourable condition of the physical properties should, therefore, be the forester's chief aim, and this he can do best by preserving the humus, especially on middling and poor soils. Humus increases the depth of the soil, absorbs from the atmosphere considerable quantities of aqueous vapour, carbon dioxide and ammonia; it is capable of holding a large quantity of water, which it gradually gives up to the lower layers of the soil; it loosens too firm a soil, and gives somewhat more consistency to a soil which by itself is too porous; finally it moderates the extremes of cold and heat. The poorer a soil the more important is the preservation of the humus, provided it is not acid.

5. *Summary.*

Summarising all the demands which forest trees make on the soil, it may be said that all species like a soil which is minerally strong, deep, porous, fresh, warm and rich in humus, such as a mild loam with a good layer of humus. Some species find the necessary conditions more on one class of soil than on another; for instance, beech, ash, elm, maple, and Austrian pine, like a certain quantity of lime in the soil, probably less on account of its chemical composition than of the physical qualities which an admixture of lime produces.

Most coniferous trees, on the other hand, are more frequently found on loamy and sandy soils.

Though all trees like a good fertile soil, the several species differ considerably as to the minimum of fertility on which they can thrive; that is to say, some are more exacting in their demands than others. In this respect the following scale is suggested:—

Least exacting are: Austrian pine, Scotch pine, Weymouth pine, birch, poplars, tree willows, mountain ash, acacia, mountain pine, white alder.

Moderately exacting are: Spruce, Cembran pine, larch, common alder, lime, osiers, horse chestnut, hazel, hornbeam, Norway maple.

Most exacting are: Silver fir, beech, sweet chestnut, sessile oak, sycamore, ash, elm, and pedunculate oak.

It will be observed that the valuable broad-leaved species are, on the whole, more exacting than the soft broad-leaved species and the conifers.

Any classification like that given above must, however, be received with some caution; its object is merely to give a general idea of the subject. In practice deviations occur constantly, according to the local conditions under which trees grow.

Section V.—Effect of Forest Vegetation on the Locality.

It has been shown in the previous sections that the condition of the locality governs the growth of forest trees. It is now necessary to consider the effect of forest vegetation on the locality, more especially on two of its factors—humus and moisture. This effect is chiefly produced by the following two agencies :—

(1.) The protection which growing woods afford to the soil and adjoining layers of air.

(2.) The humus which is formed by the fall of the leaves, branches, twigs, flowers, fruits, etc., and by certain plants growing under the shelter of the trees.

In well stocked or crowded woods the crowns of the trees form a thick leaf canopy, or complete cover overhead. If the trees are all of the same age and height, the leaf canopy is at a uniform height above the ground, that height being at first small, but increasing with age. In woods of uneven age the cover is of a somewhat different nature; it consists of groups of crowns at varying distances from the ground. In either case the cover overhead protects the soil and adjoining layers of air against sun and wind; in even aged woods more against sun, and in uneven aged woods more against wind.

Again, the trees shed their leaves, flowers, fruits, and even branchlets, while mosses and other plants, which thrive under the shelter of the leaf canopy, die; thus a layer of humus on the soil is formed. Finally the roots of the trees penetrate into the soil and keep it together.

The shelter from above, the humus on the soil, and the roots of the trees together produce certain effects, which may be summarized as follows :—

(1.) The temperature of the soil and the adjoining air is lowered during the day and raised during the night; hence the extremes of temperature are moderated, and the climate rendered more equable.

(2.) The mean temperature of the soil and the adjoining air is lowered; the reduction is greatest in summer, next in spring, next in autumn, and it is slight in winter. It is also greater in the soil than in the adjoining air.

(3.) The relative humidity of the air is increased, the evaporation from the soil reduced, and precipitation may be increased.

(4.) A favourable degree of moisture in the soil is maintained.

(5.) Noxious forest weeds are kept in check.

(6.) A steady and suitable progress in the decomposition of the humus is ensured.

(7.) An additional supply of organic matter, taken by the plants from the atmosphere and brought into the soil by the falling leaves, flowers, fruits, and twigs, decaying mosses and other plants, is procured.

(8.) The soil is protected against the mechanical action of water and air currents.

In order to produce these effects in a high degree, it is necessary that the leaf canopy should be dense, so that it not only keeps out sun and air currents, but also yields a heavy fall of leaves for the production of humus. Only certain species of forest trees possess these two qualifications. During youth most species answer, no doubt,

very well; with advancing age, however, the crowns are not only lifted higher and higher from the ground, but most species thin out considerably. The result is, that the leaf canopy becomes more and more interrupted and thinner, followed by a crop of noxious weeds, or too rapid decomposition of the humus, accelerated evaporation of the moisture, and generally a reduction of the fertility of the soil. To prevent such results, the forester must either cut over the woods before the process of thinning-out has proceeded too far, or underplant such woods, or cultivate species which are capable of maintaining a complete cover overhead up to an advanced age.

Amongst the timber trees with which this book deals, beech, silver fir, and spruce are the three species which, above all others, preserve a complete leaf canopy until, or nearly to, maturity. These are shade bearing species. All other species are, with certain modifications, less capable of preserving the factors of the locality; the greater their light requirement and the thinner their crowns, the smaller their capacity in this respect. Those least suitable are birch, poplars and acacia; next willows, most pines (with advancing age), larch, elm, Norway maple, sycamore, oak, ash and alder.

The production of humus from fallen leaves is greater in woods consisting of broad-leaved species than in coniferous woods, because the more important broad-leaved species are deciduous and shed the whole of their foliage every year, while, with the exception of larch, the conifers are evergreen. The silver fir sheds about one-ninth of its foliage annually, spruce about one-seventh, the pines about one-third to one-fourth. The pro-

duction of humus from fallen leaves is, generally speaking, greatest when the rate of height growth culminates.

The accumulation of humus depends greatly on the rapidity with which the leaves are decomposed, a process which is regulated by the species, degree of cover overhead, and the character of the locality. Generally speaking, needles decompose more slowly than leaves. Of needles, those of the larch decompose most quickly, next perhaps those of Weymouth pine, Scotch pine, and Austrian pine, last those of silver fir and spruce. Of leaves, those of ash, alder, hornbeam, lime, and hazel decompose quickly; more slowly the leaves of oak, birch, and sweet chestnut. The leaves of beech stand perhaps half-way, but as beech woods enjoy a dense shade, their accumulation of humus is much greater than that found in oak or birch woods. On calcareous and sandy soils, humus decomposes more quickly than on loam and clay soils. It is also more rapid in warm low lands than in cloudy mountain regions. The most suitable, or normal, time for the process may be put at two to three years, when the most favourable results in respect of quantity and quality of humus are produced.

A few words about each of the more important species will not be out of place here:—

Beech improves the soil in the highest degree, because it has a dense crown and yields a heavy crop of leaves, which decay slowly. Beech woods, if undisturbed, show a thicker layer of humus than woods of any other species.

Hornbeam approaches Beech in this respect, though it does not equal it.

Lime gives good shade and a heavy crop of leaves, but its timber is of such inferior quality that it is not planted for economic purposes.

Sweet chestnut sheds a heavy crop of leaves, but the leaf canopy is comparatively incomplete, admitting too much sun.

Oak and all other broad-leaved timber trees have too thin a leaf canopy to do justice, generally speaking, to the locality.

Silver fir and *spruce* are capable of preserving a dense cover overhead up to an advanced age.

Evergreen conifers, other than silver fir and spruce, though they may not possess a dense leaf canopy, are often capable of preserving the fertility of the soil for a certain period, because under their half shade mosses grow, which protect the soil just as well as a thick layer of leaves. When the conifers begin to thin out to some extent, the mosses disappear gradually; hence these species should not by themselves be treated under a high rotation. Of the conifers which are here referred to, Weymouth pine, Austrian pine, Cembran pine, and mountain pine have a fairly dense leaf canopy, and yield a considerable crop of needles, more especially Weymouth pine. Scotch pine has a thinner crown, and a tendency to open out after the age of thirty or forty years, when the moss is liable to disappear and to be replaced by a crop of grass. At the same time the density of the leaf canopy of this tree differs very considerably according to the conditions under which it is grown. The Scotch pine grown in the moist climate

of the British Isles gives a much denser cover than when grown in dry continental climates.

Larch provides but a thin leaf canopy in summer, and is leafless in winter. It begins to thin out at an early age; the moss disappears quickly, is replaced by grass, and the needles decay rapidly, so that the tree is unfit for preserving the fertility of the soil.

The power of preserving the factors of the locality which is peculiar to the several species, governs their adaptability to be raised in pure woods, a subject which will be dealt with in chapter III. of this part of the book.

Section VI.—Assessment of the Quality of the Locality.

It is the duty of the forester to select that species which is best adapted for cultivation in any particular locality; in order to attend to this duty successfully, means must be provided by which the quality, or yield capacity, of the locality can be readily ascertained. Various methods have been proposed for this purpose, of which the following two will be shortly considered here:—

(1.) Assessment according to the several factors of the locality.

(2.) Assessment according to a crop of trees already produced on or near the locality.

Whenever the second method is possible, it should be followed; only in the absence of a forest crop should the first method be adopted.

A third method may be mentioned here. It has been proposed to assess the quality of the locality according to the natural appearance of certain plants, which would depend either on the presence in the soil of certain substances, or on a certain condition of the soil. Though this holds good to some extent, the method of assessment is without practical value in sylviculture, and it need not, therefore, be dealt with in this place.

1. *Assessment of the Locality according to its several Factors.*

The factors of the locality naturally arrange themselves into two groups, those of the climate and those of the soil and subsoil.

As regards climate, it is necessary to ascertain:

(*a.*) The geographical position of the locality, that is to say, the latitude, and in some cases, the longitude.

(*b.*) The local peculiarities of the locality, such as altitude, aspect, slope, surroundings, temperature, moisture in the air, rainfall, exposure to cold or dry winds, susceptibility to late or early frosts, etc.

All these matters have been dealt with in section II. of this chapter.

Turning now to the soil, the following points, as indicated in section III., require attention:—

(*a.*) The depth of the soil.

(*b.*) The degree of porosity.

(*c.*) The degree of moisture peculiar to the soil.

(*d.*) The chemical composition.

A detailed examination of the factors of the soil is a complicated and difficult operation, which it is not intended to describe here. There is, however, a somewhat rough and ready method, which generally suffices for sylvicultural purposes, and which will be shortly indicated.

The most convenient way of examining the soil is to dig a hole, if possible in a spot which promises to yield average results. On fairly level ground the spot should be selected on a uniform part of the area, that is to say, neither in any small depression nor on any slight elevation which may exist. In hilly or mountainous localities, separate holes must be dug on the ridge, the slope and at the bottom of the valley. The depth of the hole must be at least equal to the depth to which the roots penetrate, that is to say, 3 to 4 feet. Where rock is met at a smaller depth than this, its stratification and general composition should be ascertained, as well as its effect upon the regulation of moisture and the stability of the trees. One side of the hole, at any rate, should be perpendicular, so that the thickness of the successive layers of the soil can be measured in so far as they are indicated by different colour, different degree of cohesion, and other outward signs. The depth to which the soil is coloured dark by humus should be specially noted.

This operation will show whether the soil is sufficiently deep to admit of a proper spreading of the roots, and if not, the examination of the subsoil will indicate, how far the latter can make up for the shallowness of the surface soil. The same operation will indicate what effect the depth and nature of the soil have on the degree

of moisture. Next the degree of division, or the nature of the grain of the soil, must be ascertained. This can be done by shaking a sample, if necessary of each successive layer, with about three times its volume of water in a graduated tube, until all parts are thoroughly separated; the tube is then placed in a perpendicular position and watched. As coarse grains settle more quickly than fine grains, it follows, that the time occupied compared with the thickness of the deposit indicates the degree of division of the particles. A high degree of division indicates a stiff soil, the presence of coarse grains the reverse, and thus an idea can be formed of the degree of porosity.

If necessary, the capacity to absorb water, to attract it from the subsoil, to retain it, and the hygroscopicity of the soil can be ascertained by special experiments, but in practical sylviculture they are rarely called for.

The exact composition of the soil can only be ascertained by means of a detailed chemical analysis. In practice the forester can easily acquire the faculty of distinguishing in a rough and ready manner between the several constituents. He recognizes:—*Clay* by a high degree of cohesion, a fatty feeling, active absorption of water while emitting a clayey smell, slow disintegration in water, slow drying followed by cracking, a grey colour, etc.; *loam* by a lesser degree of cohesion than in the case of clay, rougher feeling, quicker disintegration in water, and generally a more reddish colour; *lime* by active effervescence if treated with an acid, porosity, light whitish to greyish-white colour, which is, however, frequently turned red by iron, a rough but fine grained feeling, etc.; *sand* by very slight cohesion, grinding

between the teeth, or hard grainy feeling, immediate disintegration in water and rapid settling down in it, a light, glossy, shiny, yellowish-white colour, often converted into red by iron, into white by lime, into black by humus; *humus* by its porosity and light weight, peculiar smell like that of fresh garden earth, rapid disintegration in water, which remains dark coloured for a long time, blackish colour which disappears on roasting; *iron* by red colouring, etc.

In order to recognize more easily the principal constituents of a soil and their proportion, a sample may be mixed in a glass tube with about twice its volume of water, well stirred until completely dissolved, and then allowed to settle. At the bottom of the glass tube the following deposits will be observed, beginning with the lowest:—

First: The rougher grains of sand.
Second: The finer grains of sand.
Third: Lime and the coarser clay.
Fourth: The finer clay and particles of humus.

The thickness of the layers indicates the proportion of each substance.

In spite of the most persevering attempts, experience has shown that the assessment of the locality in the manner indicated above is always subject to grave errors, because the various factors may compensate each other, replace one another, or may be altogether unassessable. To make matters worse, the factors are rarely the same over extensive areas, but change from one spot to another. On the whole, the method which has just been indicated can only serve as a make-shift

when no better means of assessment are available, or as a help in the application of the method now to be described.

2. *Assessment of the Locality according to a Crop of Trees.*

When a locality has already produced a crop of trees, it may be assumed that, unless extraordinary events or irregular treatment have interfered with the development of the trees, the effects of all its factors have found due expression in such crop, which is therefore the best guide for the assessment of the quality, or yield capacity, of the locality. If, for instance, an acre of ground has produced a total quantity of 5000 cubic feet of wood in the course of 100 years, the quality, or annual yield capacity, is represented by $\frac{5000}{100} = 50$ cubic feet, in other words by the mean annual production.

The applicability of this method depends principally on the following three conditions:—

(*a.*) That the existing wood has grown up under normal conditions; in other words, that no extraordinary disturbing events have occurred which affected the health and development of the crop, as for instance, damage by cattle or deer, insects, fire, theft, removal of litter, faulty treatment, etc.

(*b.*) That the factors of the locality have not undergone any decided change, either for the better or worse, since the existing crop was formed; for instance, the stock of humus or the degree of moisture may have been affected by external interference.

(*c.*) That the existing crop is of a sufficient age to make sure that the factors of the locality have found

a thorough expression in the same, since a wood may thrive well up to a certain age and then fall off considerably.

Whenever these conditions exist to a fair extent, the method of assessment is the best which is at the forester's disposal; and in its application he need not restrict himself to a crop actually growing on the area, but may be guided by one growing on a neighbouring piece of land, provided the general conditions are the same in both cases.

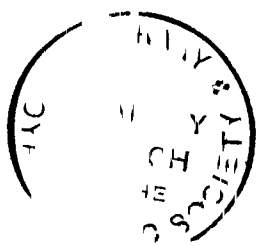
A great quantity of data bearing on the yield capacity of land has, in the course of time, been collected and brought together in so-called "*Yield Tables*," that is to say, tables which indicate the yield which an acre to land may reasonably be expected to give according to whether it belongs to one or the other quality. By way of illustration a table is given below, which indicates the final yield (exclusive of thinning) of Scotch pine woods in Germany; the localities are arranged into five quality classes, and the figures represent the mean of very numerous measurements.

GROWING STOCK OF SCOTCH PINE WOODS, IN CUBIC FEET PER ACRE.

Age of Wood.	TIMBER AND FAGOTS. Number of Quality or Yield Capacity.					TIMBER ONLY, 3 INCHES AT THE THIN END AND UPWARDS. Number of Quality or Yield Capacity.				
	I.	II.	III.	IV.	V.	I.	II.	III.	IV.	V.
20	2,320	1,530	1,290	1,060	810	790	70	30	...	...
30	3,650	2,760	2,140	1,740	1,380	2,210	1,170	830	440	360
40	4,800	3,860	2,900	2,370	1,900	3,870	2,830	1,970	1,290	900
50	5,820	4,740	3,530	2,910	2,320	5,060	3,940	2,700	2,040	1,430
60	6,750	5,420	4,060	3,360	2,670	6,020	4,690	3,300	2,610	1,870
70	7,510	5,960	4,530	3,730	2,970	6,790	5,250	3,820	3,070	2,240
80	8,140	6,400	4,950	3,990	3,190	7,420	5,720	4,260	3,350	2,510
90	8,670	6,780	5,300	4,170	3,300	7,950	6,100	4,620	3,530	2,690
100	9,110	7,090	5,580	...	...	8,390	6,410	4,910	...	...
110	9,500	7,370	5,820	...	...	8,780	6,690	5,150	...	...
120	9,780	7,630	6,010	...	..	9,060	6,950	5,340	...	...

Assuming that a Scotch pine wood contains, when 60 years old, on a fully stocked acre 4,060 cubic feet of timber and fagots, then the locality on which it grows belongs to the III. quality; if it contained 5,420 cubic feet, it would belong to the II. quality. If the number of cubic feet fell between these two figures, the locality would be classed as of that quality which it approaches nearest. For instance, if the growing stock came to 5,100 cubic feet, the locality would belong to the II. quality; if 4,500 it would be placed in the III. quality.

How tables of this kind are prepared and used is described in volume III. of this Manual.



CHAPTER II.

DEVELOPMENT OF FOREST TREES.

In dealing with the shape and development of forest trees, it is assumed that the student has already acquired a botanical knowledge of the several species, so that here only their sylvicultural characteristics need be described, more especially the shape peculiar to each species, the height, diameter and volume growth, lease of life and reproductive power.

1. *Shape.*

Different species of trees naturally develop different shapes. Some species, like spruce, silver fir and larch, have a decided tendency to form a strong stem in preference to the development of the crown. Others, like pedunculate oak, lime and sweet chestnut, develop their crown in preference to the stem. Some species are frequently forked, as ash, false acacia, and also elm. Cembran pine often shows a candelabra-like shape, especially in stony situations. The actual shape depends, however, on a variety of influences, amongst which the following may be mentioned:—

a. Growing Space.

The individual character of a tree can be best recognized if it has grown up in a free position, so that its natural development has not been interfered with. When

trees have been reared in this way their shapes can be arranged in the following classification :—

An undivided stem throughout have : Spruce, silver fir, larch, also Weymouth pine.

Divided in the upper part only are: Scotch pine, alder, beech, black poplar, Cembran pine.

Divided somewhat lower down are : Ash, Norway maple, sycamore, elm, sessile oak, sweet chestnut.

Decidedly branching with a divided stem comparatively low down : Pedunculate oak, lime, hornbeam, mountain pine.

The shape is considerably altered when the trees are grown in crowded woods, where each enjoys only a limited growing space. In that case all species have a greater tendency to the development of stem than of crown, and this in the same proportion as the species is light demanding and the growing space reduced. Thus the crown of the silver fir covers often the whole of the upper half of the tree, that of spruce the upper third (and generally a little more), also that of beech and hornbeam; the crown of larch, Scotch pine, oak, birch and aspen is reduced to the uppermost part of the stem. The effect is, that the more elevated the crown is, the nearer will the shape of the bole approach that of a cylinder, and consequently the more valuable it will be.

b. Age.

All species, when grown in crowded woods, develop during the early part of life a conically shaped crown, but when they approach their full height the crowns

differ considerably, so that the following classification applies:—

A conical crown with thin branches have: Spruce, silver fir, larch.

An egg-shaped crown have: Elm, beech, Norway maple, sycamore, birch, sessile oak.

An inverted broom shape, horizontally extended, with strong branches, have: English oak, sweet chestnut, black poplar, lime.

After the height growth has been completed the crowns of all trees become flat or rounded off, more or less extending in breadth. Only spruce makes an exception, as the leading shoot continues to grow up to a great age, though very slowly.

The practical conclusion to be drawn from these peculiarities is, that only shade bearing species, which are satisfied with a limited growing space, are capable of preserving a complete cover up to an advanced age, such as silver fir, spruce, beech, and also hornbeam. Much inferior in this respect are ash, Scotch pine and larch, chiefly because they are light demanding; also maple and sycamore. If to the demand for light is added a strong tendency to develop branches, then the interruption of the cover occurs early, as in the case of oaks (especially pedunculate) and sweet chestnut. This tendency is the more pronounced the less suited the locality is for the species.

c. Soil.

The nature of the soil influences the shape of the trees in the case of all species. Fresh, deep, fertile soils

encourage height growth. Shallow, rocky soils produce only short stems with a tendency to divide the stem and develop branches.

d. Situation.

The development of stem decreases with rising elevation, while that of branches increases. At great elevations the shape is reduced to that of a shrub or bush. Similar phenomena are observed on proceeding north, and in localities exposed to cold winds. Trees exposed to continuous strong winds, as near the sea coast, assume often a one-sided shape.

2. *Height Growth.*

The energy of height growth differs not only according to species, but is also subject to considerable modifications in the case of one and the same species, according to the age of the tree, the locality, method of formation and of treatment.

a. Species.

Amongst the trees of Central Europe, spruce, silver fir, larch, Weymouth pine and Scotch pine attain the *greatest height;* they ordinarily reach a height of 120 feet, and under favourable conditions, much more.

Next come: Oak, beech, ash, lime, elm, Norway maple, sycamore; then poplar, birch. These species do not, except under specially favourable conditions, exceed a height of 110 feet.

Beech reaches in Normandy a height of 170 feet; oak one of 150 feet, but these are exceptional heights.

Next come: Austrian pine, Cembran pine, hornbeam, alder, willow. They do not, as a rule, exceed 75 feet in height.

b. Age.

The energy of height growth during the first part of life is of special importance in sylviculture. Generally the light demanding species are at this time faster growing than the shade bearing species. Assuming favourable conditions of growth as found in the natural home of each species, they may during youth be arranged as follows, commencing with the fastest growing kind:—

Birch, larch.
Aspen, alder, Norway maple, sycamore, ash, lime, elm.
Weymouth pine.
Scotch pine.
Austrian pine.
Sweet chestnut, oak.
Hornbeam.
Beech.
Spruce, Cembran pine.
Silver fir.
Yew.

As soon as the first youth, say up to 20 or 30 years, has been passed, a considerable change occurs. Some species, like larch, and under favourable circumstances also Scotch pine and birch, preserve their fast growth until they have completed their principal height growth.

Others, like Cembran pine and hornbeam, remain

slow height growers throughout life. The majority of species, however, increase their rate of height growth considerably, and this is specially pronounced in spruce,

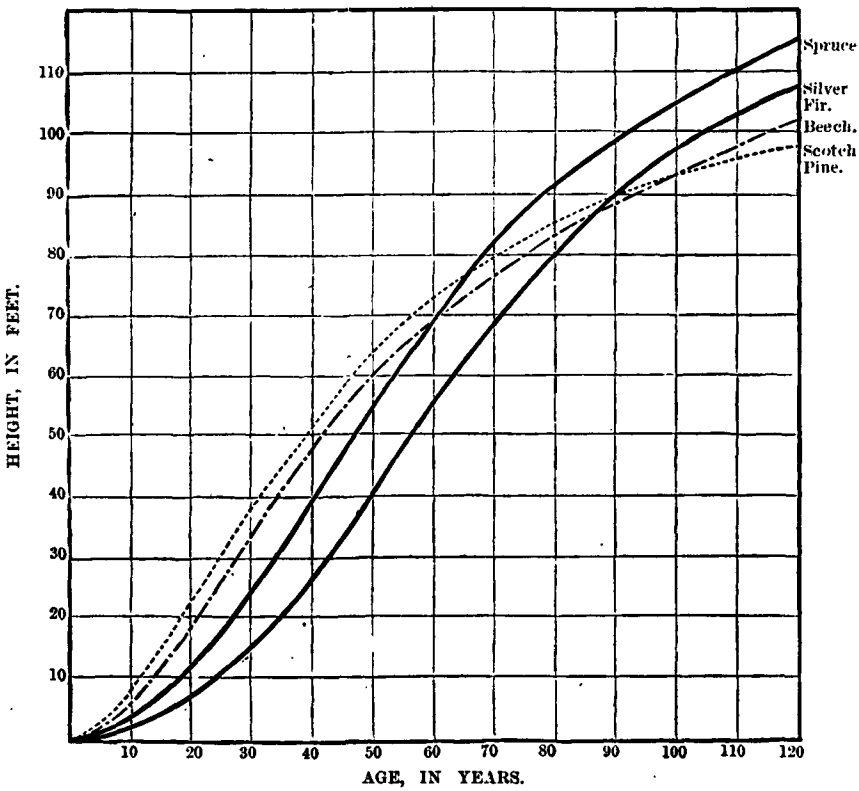


DIAGRAM ILLUSTRATING THE RELATIVE HEIGHT GROWTH OF SPRUCE, SILVER FIR, BEECH AND SCOTCH PINE; according to the Yield Tables of Baur (Spruce and Beech), Lorey (Silver Fir), and Weisse (Scotch Pine).

silver fir, also beech and oak, so that they soon reach and surpass trees like ash, Norway maple, sycamore, aspen, which do not grow at the same rate.

The duration of height growth in the more advanced periods of age is greatest in those species in which the

development of stem naturally predominates over that of the crown, such as spruce, silver fir and larch, and these species reach ultimately the greatest height.

Amongst broad-leaved species, sessile oak, elm and beech preserve their height growth longest. In the case of the other broad-leaved species, the crown is rounded off at an earlier period, when height growth ceases.

c. Locality.

The factors of the locality have a decided effect upon height growth. It has already been pointed out that deep, fresh, fertile soils produce much higher trees, than shallow, dry, rocky soils. Elevation exercises also a considerable influence. It may be said that every species shows its greatest height growth at that elevation which offers the most favourable climatic conditions for its growth; above that elevation the height growth decreases, and in many cases also below it. In situations exposed to strong air currents and other unfavourable influences, height growth is comparatively small.

d. Methods of Formation and of Treatment.

They affect the height growth principally on account of their effect upon the establishment and preservation of a complete leaf canopy. The more complete the cover, the better will be the effect upon the height growth of most broad-leaved species, Scotch and other pines; it is less pronounced in the case of silver fir, spruce and larch. In this respect the manner in which thinnings are conducted is of paramount importance, a subject which is dealt with in volume II. of this Manual.

3. *Diameter Growth.*

Generally speaking, the increase of the diameter of the stem (or bole) is, in the case of all species, fairly proportionate to the height growth, that is to say, both height and diameter growth are greatest at the same period of life. In the case of light demanding species the diameter increment often reaches its maximum between the 20th and 30th year of age, a good increment being maintained up to the 50th or 60th year, when it commences to fall off. Shade bearing species and oak reach the maximum diameter increment later on, but it is also longer maintained, often up to the 90th year, before it commences falling off to any considerable extent.

Apart from species, the diameter increment depends on—

(*a.*) The quality of the locality.

(*b.*) The amount of light which the tree receives and can utilize, in other words the extent of the crown, which is governed by the growing space.

Limited space in a crowded wood reduces the diameter increment, a free position increases it; hence height growth and diameter growth demand in most cases opposite conditions. It is the business of the forester to give the most profitable growing space, in other words to give to the individual trees from time to time sufficient room to encourage diameter growth, without endangering the progress of the height growth.

The effects of a great surface of foliage and unimpeded

enjoyment of light are very remarkable, when healthy trees, which have been raised in a crowded wood, are gradually given more growing space. Such an opening out can, provided the period of height growth has not come to an end, produce a revival of the diameter increment, after its maximum has been passed, due to an increased leaf surface, or to a greater intensity of action, even if the leaf canopy is not materially extended.

Where both great height and diameter growth are wanted, it is best to keep the wood crowded during youth, and to give only a moderate growing space to each tree until towards the end of the principal height growth, when the growing space of each remaining tree should be gradually increased, so as to develop more extended crowns and greater diameter growth. This is only possible while height growth is still going on; once that has stopped, the thinning out will not be followed by any appreciable extension of the crowns, which can only be produced by transferring to it the energy of height growth. The possibility of such a transfer is longest preserved in silver fir, spruce, larch, oak, and beech.

4. *Volume Growth.*

The increase in volume depends on both height and diameter growth, and that method of treatment which promotes each in due proportion, must ultimately yield the largest volume; in other words, woods should be neither too crowded, nor too open. In the one case thin tall trees, and in the other short thick trees would be produced. The most favourable density of the crop can only be ascertained by accurate statistics. General ex-

perience has shown that the greatest volume is ultimately obtained, if the woods are fairly heavily thinned from their youth onward, but this interferes often seriously with the quality of the timber.

Apart from these general considerations, a great difference exists in the volume produced by the several species when grown in regular woods; in this respect some of the more important kinds may, according to the latest investigation, be arranged in the following manner, commencing with that species which produces the greatest average increment, calculated for a prolonged space of time:

Silver fir.
Spruce.
Weymouth pine, Larch.
Scotch pine.
Beech.
Oak.
Ash.
Birch.

Hence, coniferous woods are called fast growing, as compared with woods which consist of broad-leaved species.

The increment laid on by an individual tree does not by itself govern the increment produced per acre, because the latter is represented by the increment per tree multiplied by the number of trees per acre. For instance, if an acre of ground can hold 100 mature silver firs, each of which has a volume of 100 cubic feet, the total volume per acre will be 10,000 cubic feet; if an acre can hold 50 mature oak trees, each with a volume of 150

cubic feet, the total volume per acre will be only 7,500 cubic feet, or 2,500 cubic feet less than in the case of silver fir.

The number of trees which find room on an acre of ground depends chiefly on

(a.) The light requirement of the species.

(b.) The tendency of the species to develop the crown in preference to the stem.

Hence, an acre stocked with the light demanding birch, ash, or spreading oak, contains a smaller number of trees and a smaller volume than an acre stocked with beech. Again, larch and Scotch pine woods contain fewer trees and a smaller volume per acre than silver fir and spruce woods. The following data will illustrate this; they give the average growing stock per fully stocked acre at the age of 120 years, in localities of the first quality in each case:—

Silver fir	=	17,400 cubic feet per acre.
Spruce	=	14,500 ,, ,, ,, ,,
Scotch pine	=	9,780 ,, ,, ,, ,,

5. *Duration of Life.*

A great difference exists in the age which the various species attain ultimately. If grown under conditions which are in harmony with their requirements, the yew lives for more than 1000 years, the oak comes often near that age, if it does not exceed it; lime, elm and sweet chestnut reach and surpass an age of 500 years; beech reaches a similar age under favourable circum-

stances, but ordinarily both beech and silver fir die before that age. A limit of 300 years may be assigned to ash, maple, sycamore, spruce, larch, Scotch pine and hornbeam; while aspen, birch, alder and willow live, under ordinary conditions, little beyond 100 years.

In Forestry the trees are, as a rule, cut over long befor they have reached the natural end of their life. Never theless many cases occur, where trees have been grow under conditions which are not quite in harmony wit their requirements, so that they die, or at any rate fal off in health and growth long before they would, in th ordinary course, be cut over; hence it is of importanc to consider the conditions under which the growth con tinues to be healthy to an advanced age.

In the first place, the nourishing organs, crown an roots, must be able to develop normally in accordanc with the requirements of the tree at the different periods of age; in other words they must be given at all times the required growing space, without, however, checking their height growth or interrupting the cover overhead. Unless a tree is provided with a sufficient quantity of organs, it will not be able to overcome successfully internal and external damage which endangers its life. The power of resistance in this respect differs considerably in the various species. It is great in oak, hornbeam, lime, willow, elm, yew, Cembran pine, but small in alder, Norway maple, sycamore, beech, spruce.

The second condition of longevity is, that the locality should offer to the tree all it requires for a proper development. On the whole it may be assumed that where a tree is indigenous, it finds all it requires (though this is not without exceptions). Localities with different

factors are liable to be unsuited to the species, either from offering too little or too much in respect of temperature, moisture, or insufficient nutriment in the soil, depth, etc. Either case may be injurious to the development of the tree, and especially to the quality of the timber produced. For instance, larch and spruce are naturally fond of a cool climate; by transferring them to the dry and warm air of the low lands, they generally grow much more quickly, but yield inferior timber, are shorter lived, and subject to more dangers, than in their mountain home.

Trees raised in fully stocked compact woods do not live as long as when raised in the open. Moreover, in that case various other important considerations must be taken into account. After having weighed these, the forester decides on the age limit which is most likely to realize the objects of management.

What the objects of management are has been indicated in the Introduction of this part. It will suffice to add here, that they govern the determination of the *rotation*, or the time which elapses between the formation and final cutting over of a wood. Whatever motives may influence the selection of the rotation from a sylvicultural point of view, it must always be remembered, that it should be so fixed under the method of natural regeneration as to admit of a proper regeneration of the wood, whether by seed or coppice shoots; in other words the wood must be cut over while the reproductive power of the species is in an active condition.

6. *Reproductive Power.*

The tendency to reproduce the species manifests itself throughout nature; in fact the energy devoted to reproduction is frequently stronger than that bestowed upon the preservation of life. The forest trees, in obedience to this law, produce seed during a considerable part of their life, and in large quantities.

In sylviculture, the reproduction of trees and woods is effected in two distinct ways, namely :—

(*a.*) From seed.

(*b.*) From shoots which spring from the stool, followed, in many cases, by the division of the mother plant.

a. Reproduction from Seed.

This is the more common form of reproduction, and on it depends the regeneration of high forest.

The greater the production of seed, and the better its quality, the more assured is reproduction; both quantity and quality of the seed depend on the age of the trees, the locality, the available light and the species.

(1.) *Age.*—The first point of interest is the time when the various species commence to produce seed fit to germinate. Apart from single trees here and there, the average period may be placed as follows,* in the case of trees grown in regular woods :—

At the age of 25—30 *years:* Mountain pine, birch, white alder, aspen, acacia.

* According to Hess.

At the age of 30—40 *years:* Scotch pine, Austrian pine, Weymouth pine, larch, Norway maple, common alder, lime, horse chestnut.

At the age of 40—50 *years:* Hornbeam, elm, ash, sycamore.

At the age of 50—60 *years:* Spruce, sweet chestnut.

At the age of 60—70 *years:* Beech.

At the age of 70—80 *years:* Silver fir, Cembran pine, oak.

The most favourable age for the production of seed is, ordinarily, that when the principal height growth is about to be completed, and when an extension of the crown takes place; in other words, when the individual tree lays on its maximum volume growth. At that period the best seed is produced. Younger trees produce larger but fewer seeds; older trees produce more numerous but smaller seeds.

(2.) *Locality.*—Temperature is of first importance; where that is deficient, the production of seed is seriously endangered. Tree seeds contain a comparatively large proportion of ash, and their production necessitates increased assimilation of substances from the soil; hence fresh fertile soils produce more and better seed than poor soils. A crop of seed also requires large quantities of nitrogen.

Some species no longer produce seed fit to germinate (or only in small quantities) when they have been cultivated beyond the limits of their natural home, as, for instance, sweet chestnut and elm in the north of England. Other species are very accommodating in this respect, such as birch and Scotch pine.

(3.) *Light.*—Increased assimilation requires an increased supply of light to the crown; hence trees growing in the open produce more seed, than those hemmed in. Suppressed trees rarely produce seed.

(4.) *Species.*—The power of reproduction from seed differs considerably in the case of different species; it depends on the total quantity of good seed produced during a certain period, or on an average annually. The quantity of seed is governed by two things:—

(*a.*) The average yield of each seed year.
(*b.*) The frequency of seed years.

As regards the average yield per seed year, the species can be arranged into two sections as follows *:—

Heavy crops: Beech, oak, spruce, Scotch pine, birch, hornbeam, elm, alder, aspen, willow.
Lighter crops: Ash, maple, sycamore, silver fir, larch.

On the other hand, the species may, as regards frequency of seed years, be arranged as follows:—

Beech seeds only after intervals of six, eight, ten, and even more years.
Oak, spruce, Scotch pine, and alder seed, on an average, every three to five years.
The remaining species seed after shorter intervals, and some do so every year.

Taking both factors into consideration, the species may be arranged into the following scale:—

Best: Birch, aspen, willow.
Next: Scotch pine, spruce, elm, hornbeam.

* According to Gayer.

Next: Norway maple, sycamore, silver fir, larch, lime, oak, alder, ash.

Last: Beech.

Another very important point is the size and nature of the seed. Species which have a small, light, and winged seed reproduce themselves more easily and extensively, than those with a heavy or wingless seed. Moreover, it so happens, that the species with light or winged seeds, such as birch, aspen, willow, Scotch pine, spruce, are comparatively less sensitive in respect of the factors of the locality, than, for instance, oak, beech, silver fir, maple, and sycamore, with their heavy seeds. The consequence is, that the power of reproduction peculiar to the first named species is much greater than that of the last mentioned. Instances where oak and beech are ousted by Scotch pine and spruce can be frequently seen, while the latter, in their turn, have to struggle against the inroads made on them by birch, aspen, and willow.

b. Reproduction from Stool shoots and Root suckers.

This method of reproduction applies to coppice woods. It occurs in two ways :—

Either : On that part of the stem which remains, after a tree has been cut down, dormant or adventitious buds develop into shoots; they are called "stool shoots."

Or : Buds are formed on the roots, which develop into aërial shoots, such shoots being called "root suckers."

In both cases the nourishment and growth of the new individual depend on the continued root activity of the mother plant. If the new individual is capable of producing root buds and of developing them into roots, it becomes independent of the mother plant; in such a case reproduction is established by a division of the mother plant.

Reproduction in the manner just described is strongest during youth, and the faculty is maintained for different periods of time according to species. The better the conditions of growth, the longer will the reproductive power be maintained. A thin and young bark reproduces more freely than thick and old bark. Favourable places are the neck of the root stalk and wounds.

An essential condition of a copious reproduction in the manner described is full enjoyment of light; stools standing under cover develop either no shoots or only feeble ones.

As regards species, the following classification may be made:—

The Reproduction is maintained beyond an age of 40 *years in the case of:* Oak, sweet chestnut, hornbeam, elm, alder.

It ceases at an earlier age in: Beech, birch, Norway maple, sycamore, ash.

The conifers have no power of reproduction of this class worth mentioning. Larch shows best amongst conifers, and the three needled pines next.

Some species produce only stool shoots, others root suckers, and others again both:—

Principally stool shoots: Oak, hazel, hornbeam, beech, elm, sweet chestnut, lime, black poplar, alder, ash, sycamore, maple, willow, birch.

Principally root suckers: Aspen, white alder, false acacia.

The age to which stools live differs considerably, according to species and locality. While the stools of oak and hornbeam last for centuries, those of beech are comparatively short lived. The osiers in the Thames valley, if coppiced annually, are said to last only about 10 years.

CHAPTER III.

CHARACTER AND COMPOSITION OF WOODS.

In sylviculture trees are only in exceptional cases reared in free positions; as a general rule they are grown in considerable masses, which form more or less crowded woods. Such woods may be composed of one species only, or they may contain a mixture of two or more species; in the former case they are called *pure woods*, and in the latter *mixed woods*. Naturally pure woods occur only under certain conditions, as, for instance, when the factors of the locality suit only one particular species, or when the vitality and energy of one species has gradually ousted all others. Species which appear naturally in pure woods are called *gregarious*. The bulk of the pure woods, which exist at present in Europe, are the result of artificial interference. By far the greater number of natural woods are mixed.

Section I.—Pure Woods.

Practically, woods are rarely quite pure, because in most cases specimens of other species, which it was not intended to rear, make their appearance uninvited. As long as such an admixture is slight, accidental and not taken into account by the management, the character of the pure wood may be said to be preserved.

The principal advantage of pure over mixed woods is, that they are easier to manage, because the requirements of only one species have to be considered. On the other hand, they have considerable disadvantages as compared with mixed woods, which will be dealt with in section II.

The fitness of a species to be raised in pure woods depends on its capacity to preserve, or even improve, the factors of the locality, in other words, whether the species preserves a complete leaf canopy to an advanced age, and secures the accumulation of a sufficient layer of humus. As indicated in section IV. of chapter I., beech, silver fir, and spruce act most beneficially in this respect, and next to these some of the pines. Apart from them, several others are frequently grown in pure woods, such as oak, larch, Scotch pine, birch, and willows, on account of their great utility.

Of the remaining, or so-called dependent species, few are found in pure woods, and then only under special circumstances; for instance, hornbeam replaces beech in frost localities, Cembran pine and mountain pine occur at high elevations, maritime pine on dunes near the sea-shore.

What has been said above is, however, subject to exceptions in the following cases:—

(1.) If the factors of the locality are such, that an imperfect cover and want of humus do not materially injure them; as in deep fertile soils, which enjoy an ample and well distributed rainfall, or which are kept moist by ground water, or irrigation.

(2.) If the woods are treated under so short a rotation,

so that they are cut over before any excessive interruption of the leaf canopy has set in.

(3.) If the object is to utilize localities which are only fit for certain species; for instance, alder and willow on wet soils, hornbeam in frost localities, etc.

(4.) If only one species finds a ready market, or is required for a special purpose.

Except in such cases, all dependent species should be raised in mixed woods.

Section II.—Mixed Woods.

A mixed wood may be so arranged that every tree of one species alternates with a tree of another species, in which case the mixture is called one *by single trees*. Or a group of trees of one species may alternate with a group of trees of another species, called a *mixture by groups*; in the latter case the groups must not be of such extent, that each acquires the character of a pure wood. Mixtures may also be arranged in alternate lines or strips.

Mixed woods may be:—

(*a.*) Permanent or temporary.
(*b.*) Even aged or uneven aged.

Temporary mixtures are ordinarily called for in the following cases:—

(1.) When the intention is to obtain an early return, by the removal of one of the species, which should in that case be of rapid growth.

(2.) When a tender species has to be protected

(nursed) during early youth against frost or drought, as beech and silver fir, and to a less degree oak. In this case a hardy and fast growing species, such as Scotch pine, larch, birch, is raised either simultaneously or beforehand, and removed when the tender species requires no further protection. Near the sea coast, it is generally necessary to grow, first, very hardy trees, so as to establish sufficient shelter; more valuable trees may afterwards be introduced between the lines of the nurses.

(3.) When both the above objects are combined.

Permanent mixtures are established, because they are considered to have advantages over pure woods.

1. *Advantages of Mixed Woods.*

(*a.*) Mixed woods admit of a more complete utilization of the factors of the locality, and consequently they produce a larger quantity of wood, if the mixture is suitably arranged. Each spot can be stocked with the species which is best adapted to the factors of the locality; hence increased production follows.

(*b.*) Unless very extensive areas are available, only mixed woods enable the forester to meet the various demands of the market. In the case of pure woods, and if a regular annual yield of each of several species is expected, a complete series of age gradations is required for each species, which, in the case of a limited area, would lead to small annual cuttings. For instance, if the intention is to grow five species on an area of 500 acres under a rotation of 100 years, each cutting would extend, in the case of pure

woods, over one acre, while in the case of a mixed wood, the annual cutting may be five acres in one block.

It should also be noted, that only a few species are fit to be grown in pure woods. At the same time many of the other species yield a very superior quality of timber, or valuable minor produce. All these would more or less disappear under the system of pure woods, or at any rate they would not thrive so well and would not develop equally fine boles, as if grown in mixed woods. Large sized timber of many light demanding species can only be produced by mixing them with shade bearing, and consequently soil preserving species.

(*c.*) Many species suffer less from external injurious influences, such as wind, fire, frost, snow, insects, fungi, if raised in mixture with other more hardy species.—A shallow rooted species had best be grown mixed with a deep rooted species.—Conifers are less exposed to damage by fire or snow, if mixed with broad-leaved species.—Insects are less dangerous in mixed woods, as they generally attack only one of several species; moreover birds, the great insect destroyers, are more numerous where broad-leaved trees grow, than in pure coniferous woods.—Damage from fungi is also considerably less in the case of conifers which are mixed with broad-leaved species.—A hardy species mixed with a tender species protects it against frost, drought and injurious air currents.

(*d.*) Mistakes made in the selection of species can be more easily rectified in mixed, than in pure woods. The suitability of a locality for a certain species is not always apparent at the outset; in the case of mixed

woods the species which is least suitable can be removed at the time of thinning.

(*e.*) For the above reasons, mixed woods must, on the whole, yield better returns than pure woods.

(*f.*) Finally, mixed woods increase the artistic beauty of a country.

2. *Disadvantages of Mixed Woods.*

It is frequently described as a disadvantage of mixed woods, that their natural regeneration is more difficult, than that of pure woods. No doubt, different species require different conditions, if natural regeneration is to be successful. More especially the cover of the mother or shelter trees must be more open where a light demanding species is to be regenerated, than in the case of a shade bearing tender species. The shelter, for instance, which suits the beech, would probably kill young oak seedlings. Again, certain species, such as spruce, produce so much seed, spring up so easily, and would take possession of so much ground, that other species, like beech, would have little chance of coming up in sufficient numbers. These objections are undeniable, but they are, after all, not of such importance as might appear at first sight. In the first place, the mother trees can be so selected, that one species is favoured against the others. Secondly, the surplus regeneration of any one species can be removed in the first thinnings. Thirdly, the species can be arranged in small groups. Fourthly and chiefly, the best procedure is, to regenerate naturally with special reference to one species, and to introduce the others (as far as necessary) artificially.

In this manner the forester can produce the desired proportion of the several species with almost mathematical accuracy. On the whole, mixed woods offer such substantial advantages over pure woods, that the slight disadvantages which can be advanced against them are considerably more than counterbalanced.

3. *Rules for the Formation of Mixed Woods.*

The advantages of mixed woods, which have been detailed above, will only be realized under certain conditions, the more important of which are the following:—

(*a.*) The locality must be, *a priori*, suitable for the favourable development of each of the species in the mixture.

(*b.*) The mixture must be of such a nature that the factors of the locality do not suffer; on the contrary, they must, if possible, be improved. This will only be the case if the principal, or more numerous, species is soil improving. As indicated above, exceptions occur when woods are treated under a short rotation, or when the quality of the locality is such, that it does not require to be assisted by the improving action of the trees growing on it.

(*c.*) The mixture must be so arranged that one species does not oust the others, and establishes a pure wood. The excessive development of one species may be detrimental to the others, or even kill them outright. In this respect the toughest and least sociable species carries the day, these qualifications being dependent on

shape, light requirement and height growth of the species.

Shape.—Each species must be given that growing space which is required for its proper development. In this respect the several species differ considerably. Conifers, for instance, have a different shape from broad-leaved species. Again, some species are better able than others to stand an infringement of their proper growing space. Thus, the broad-crowned oak is liable to suffer considerably in crowded woods, while spruce stands an infringement of space comparatively easily.

Light requirement.—The mixture must be so arranged that the light demanding species are not likely to be shaded by other trees; in fact, they must have their heads free and exposed to the light. Some species, such as silver fir and beech, like, and even require, some shelter during early youth. Mixtures should be so arranged as to provide such shelter, whenever it is required. After the first few years no species actually requires shade, and then species are either shade bearing or light demanding. In most cases the former will bear the shade of the latter, but the reverse is not the case.

Height growth.—All species which demand space and light when mixed with species of an opposite nature, must be of quicker height growth than the latter. Hence the relative height growth of the species must be fully considered in deciding on the nature of the mixture. In many cases it is necessary to produce woods of uneven age, in order to prevent the light demanding species from being overgrown and suppressed by the other species.

Assuming then, that the locality suits in a general

way all the species to be mixed, the following rules govern the selection and formation of mixtures :—

First Rule.—The ruling (more numerous) species must be soil improving.

It has been stated above under what conditions exceptions from this rule are admissible.

Second Rule.—Shade bearing species may be mixed with each other, provided their height growth is of the same rapidity, or the slower growing species can be effectually protected against the faster growing.

Third Rule.—Shade bearing species may be mixed with light demanding species, if the latter are either faster growing, or are given a start.

To prevent the shade bearing species being kept back in its growth it should be more numerous than the light demanding species.

Fourth Rule.—Two or more light demanding species should not be permanently mixed, because the soil deteriorates, and the faster growing suppresses the slower growing species.

Exceptions to this rule are admissible :—

(*a.*) On very fertile localities.

(*b.*) On very inferior localities, where nothing else will grow.

(*c.*) If the wood is treated under a short rotation, or as coppice.

Temporary mixtures of two or more light demanding species occur frequently, especially where a slower growing species has to be protected against frost or drought ; for instance, oak with nurses of larch, Scotch pine, or birch.

Fifth Rule.—The circumstances of each case must decide whether the species should be mixed by single trees, groups, lines, or strips.

Two shade bearing species of equal height growth, for instance, may be mixed by single trees, but if the quality of the soil changes from place to place, it may be desirable to arrange the mixture by groups, placing each species on the more suitable spots. Again, if a light demanding species is to be raised with a faster growing species, the mixture should be by groups, and not by single trees. In such cases the groups are frequently given the shape of strips. Oak and beech are now so mixed in the Spessart mountains, that the groups of oak extend over areas ranging from one to ten and even more acres, the rest of the area being taken up by beech. In this way the suppression of the oak by the beech is prevented.

All mixtures may be brought under one of the following three classes:—

Mixtures of shade bearing species.
„ „ shade bearing and light demanding species.
„ „ light demanding species.

4. *Mixtures of Shade bearing Species.*

It is a general rule that the permanent preservation of a mixture becomes more difficult in the same degree as the species to be mixed differ in respect of light requirement, rate of height growth, suitability of locality, and shape of trees. The ordinary European shade bearing species approach each other in these respects;

hence in their case the mixture is comparatively easy to maintain, and they may generally be raised in woods of even age or nearly so.

a. Mixtures in High Forest.

(1.) *Silver fir and spruce.*—These two species resemble each other as regards shape. They differ somewhat in their demands on the locality, but over extensive areas both find suitable conditions for a healthy development. They are both shade bearing, but silver fir more so than spruce. The most important point is, that spruce grows somewhat more quickly during youth and is likely to injure the silver fir, but when the latter has once pushed its head to the light the two species hold their own against each other. In order to get the silver fir safely over the first 20 or 30 years it must be assisted against the spruce either by giving it a start of 5—10 years, or arranging the mixture according to groups, or cutting away the spruce where it threatens the silver fir.

The advantages of the mixture are principally the following :—

(*a.*) Spruce protects silver fir against frost and drought during early youth.

(*b.*) Silver fir protects spruce against storms in after life.

(*c.*) Spruce, when mixed with silver fir, is somewhat less exposed to damage by insects and snow.

(*d.*) The annual production of wood per acre is increased.

(2.) *Silver fir and beech.*—They differ in shape but

make very similar demands on the locality. Both are highly shade bearing. Beech grows somewhat more quickly in youth but more slowly in after life (see diagram on page 221). During the former period silver fir, and during the latter beech, must be somewhat assisted, or the mixture arranged by groups.

Both species thrive better in mixture, which is altogether an excellent one.

(3.) *Spruce and beech.*—They differ in shape, and make somewhat different demands on the locality, especially in respect of the degree of moisture and depth, spruce requiring more moisture, and beech greater depth. Nevertheless, soil which is suited for beech, will also do for spruce, but not always the reverse; in the moister parts spruce should predominate, and in the drier parts beech. Both are shade bearing, spruce somewhat less so. The rate of height growth is a more serious matter. During youth beech grows frequently more quickly, but afterwards spruce; they must be protected accordingly, the one against the other. On the whole, beech is more in danger of being suppressed than spruce, because under ordinary circumstances the latter is more pushing and aggressive. Spruce is only threatened in localities which are specially suited to beech.

Beech has a most beneficial effect upon spruce in respect of danger from wind, snow, insects, and fire. At the same time, beech produces finer boles in this mixture than if grown pure. Where beech timber is little in demand, it should not occupy more than about $\frac{1}{4}$th of the area against $\frac{3}{4}$ths occupied by the spruce.

(4.) *Beech and hornbeam.*—This is a mixture of subordinate importance. The timber of hornbeam is

frequently more in demand, but beech yields a larger volume. Hornbeam grows somewhat more quickly at first, but on the whole it is left behind by beech. In some localities, especially those exposed to frost, hornbeam forms a suitable substitute for beech in mixed woods.

b. *Mixtures in Coppice Woods.*

In coppice woods it is always desirable to mix some hornbeam with the beech, because the latter by itself is rarely able to maintain a full crop, owing to its inferior reproductive power from the stool; hornbeam is possessed of an almost indestructible reproductive power by stool shoots. Care is required to prevent the hornbeam from ousting the beech.

In coppice with standards also, the underwood should consist, at any rate partly, of hornbeam, and not altogether of beech.

5. *Mixtures of Shade bearing with Light demanding Species.*

While the shade bearing species much resemble each other in character, considerable differences exist between light demanding and shade bearing species in respect of shape, height growth, light requirement and duration of life; hence the maintenance of such mixtures requires great care and skill.

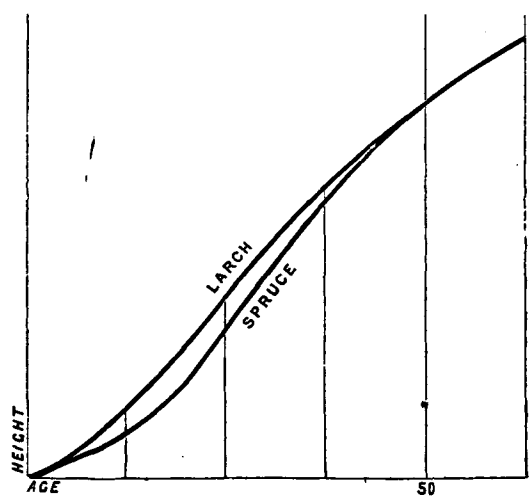
Most of the light demanding species, such as oak, larch, ash, as well as the moderate shade bearing Norway maple and sycamore, are raised principally for timber and less for firewood; they require full enjoyment of light throughout life, but they cannot reach timber size and

maintain the factors of the locality without the assistance of the shade bearing species; it is no longer sufficient to place each species in groups, and in order to meet the requirements of the case, *it is generally necessary to grow uneven aged woods.*

The principal object in all such mixtures is the full development of the timber yielding, light demanding species, while the shade bearing species, though more numerous than the former, practically take the second place in importance. The light demanding species which deserve special mention in this place are:—Larch, Scotch pine, oak, ash, sweet chestnut, elm, birch, aspen and willow; also the lime, Norway maple and sycamore, which stand about half way between light demanding and shade bearing species.

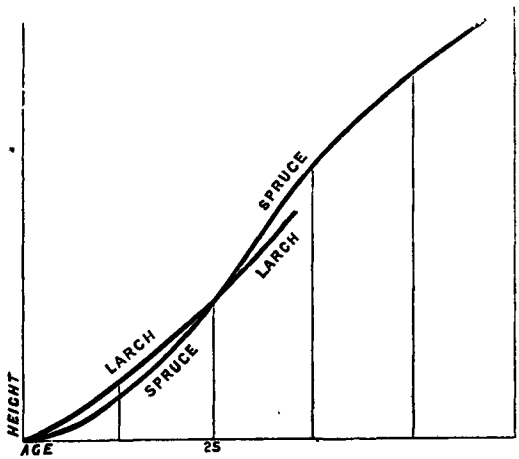
a. *Mixtures in High Forest.*

(1.) *Larch in mixture with shade bearing species—Larch and spruce.*—If the two species are of the same



On Soil specially suited to Larch.

age, the larch goes ahead at once and leaves the spruce behind. On soil which suits the larch, the tree will not be caught up by the spruce before the 40th or 50th year or even later, when they will grow up together. On localities which are less suited for larch, the spruce will catch it up much earlier, by the 15th to 25th year, pass and suppress it, so that it gradually disappears. In such cases the larch must be given a start, the result



On Soil less suited to Larch.

being an uneven aged wood. The best method is, to raise larch pure, and to bring in the spruce when grass begins to replace the moss, that is to say, at the age of 20—30 years. When the spruce has established itself, all larches, which are not likely to develop into fine trees, should be removed.

It is well known how much larch suffers from cancer when grown outside its natural home. Until means have been found by which that disease can be prevented, the only way to reduce the damage to a minimum

is, to isolate the larch trees, by mixing them with another species, for which spruce is fairly well adapted.

Larch and silver fir.—This is a still better mixture than larch and spruce, as silver fir grows somewhat more slowly during youth than spruce; otherwise the relative height growth is much the same. As silver fir requires better soil than spruce, the larch thrives admirably in all localities where silver fir grows, provided the mixture is arranged judiciously.

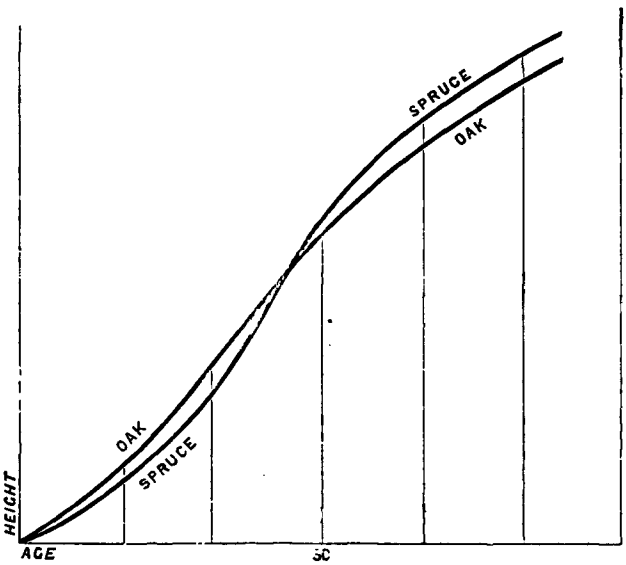
Larch and beech.—This is an excellent mixture. Larch grows quickly enough to maintain itself in the even aged form, but it is still better to start with pure larch and bring in the beech, when the former is 20 to 30 years old. The most suitable localities are those with a fresh deep soil on northerly or easterly aspects.

(2.) *Scotch pine in mixture with shade bearing species.*—The Scotch pine very much resembles the larch in its bearing towards the shade bearing species. The even aged form does very well in the majority of cases. In the uneven aged form, spruce, silver fir or beech need not be brought in until the Scotch pine has reached the age of 30—40 years, as it begins to thin out somewhat later than the larch. The Scotch pine must not be too numerous, or its shade may injure the other species in the uneven aged form, as well as during youth in the even aged form.

Both Scotch pine and larch afford excellent protection against frost and drought to silver fir and beech during their tender youth, and also to spruce, though the latter requires such protection in a less degree than the former two species.

Scotch pine and hornbeam occur sometimes together, especially in frost localities, where the hornbeam replaces the beech. Hornbeam is liable to suffer considerably from the shade of the Scotch pine, so that it is frequently reduced to an underwood, which should be periodically coppiced.

(3.) *Oak in mixture with shade bearing species—Oak and spruce.*—Natural mixtures of oak and spruce are



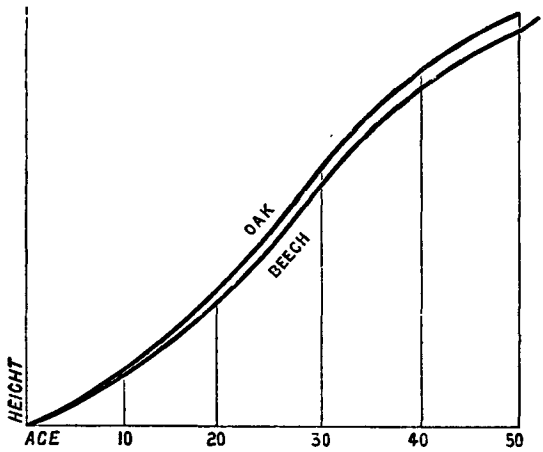
rare, owing to the different character of the two species. Oak is at home in low warm situations, spruce in cool high places. Oak thrives best on loose, warm, deep soils with a good measure of water in the subsoil; spruce requires moisture near the surface, and it is satisfied with a moderately deep soil. Oak requires much light, heat and space; the demands of spruce are more moderate in these respects. Oak is inclined to develop large branches; spruce grows more in height,

Nevertheless, artificial mixtures of the two species are advocated by some foresters. Oak grows faster than spruce during youth; later on spruce passes the oak, and the latter has no chance if mixed by single trees in even aged woods. It is necessary to place the oak in groups, and even then it does not always develop satisfactorily. The best arrangement is to plant oak pure and to bring in the spruce when the oak begins to thin out. It has, however, been noticed that the oak becomes stag headed when under planted with spruce, a phenomenon which is by some foresters believed to be due to the great consumption of water by the spruce; hence the mixture is only admissible under favourable conditions, or when the spruce is cut out at a comparatively early age before it has had time to injure the oak.

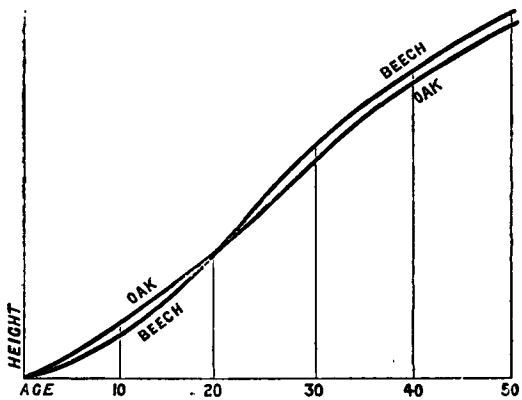
Oak and silver fir.—This is a better mixture than that of oak and spruce, as the two species resemble each other more in their demands on the locality. Oak requires a start, or it will be passed at about middle age and suppressed by silver fir. The best plan is to plant oak pure, and to bring in silver fir when the former begins to thin out.

Oak and beech.—This is a most suitable mixture, as the two species stand sufficiently near each other in respect of locality and shape; moreover, they are found naturally together. The beech has been called the oak's nurse. The oak finds in the mixture all the advantages of a permanent complete shading of the ground, accompanied by a heavy fall of leaves, a thick layer of humus, and freshness of the soil; it thus attains great height and a clear bole of considerable length.

The oak requires to have its head free throughout life. It grows more quickly than beech wherever the



On Localities suitable to Oak.



On Localities less suitable to Oak.

climate and soil suit it in respect of moisture and depth. In such localities the mixture may be arranged by single trees. In less favourable localities the oak is left behind by the beech, and then the former, in single trees, is lost; hence the mixture must be

arranged by groups, or the oak given a start, the beech being brought in when the oak commences to thin out, that is to say, between the 30th and 60th year, according to circumstances.

Oak and hornbeam.—This mixture may be desirable in localities which do not suit the beech, as for instance in frost localities, or moist deep sandy soils of the low lands. The oak grows quickly enough to hold its own against hornbeam. In this mixture the hornbeam is frequently treated as coppice.

(4.) *Norway maple and sycamore in mixture with the more shade bearing species.*—Such mixtures require a fresh, deep and fertile soil. During early youth both maple and sycamore grow more quickly than spruce, silver fir, and beech, but later on they are passed by the shade bearing species. Hence it is necessary to place the maple and sycamore in groups, or to give them a start in age.

(5.) *Ash in mixture with shade bearing species.*—The best mixture is ash and beech; not so good is that of ash and silver fir, and still less that of ash and spruce.

Ash, like the maples, grows first more quickly than beech, but is generally passed by the latter later on, hence it should be placed in groups in the moister parts of the locality. Where ash occurs pure, it should be underplanted with beech before its height growth has been completed.

(6.) *Elm in mixture with shade bearing species.*—Elm does best in mixture with beech, or perhaps hornbeam. The mixture of elm with spruce and silver fir is less desirable. Elm requires a locality with sufficient warmth, or else it will not develop into a large sized

tree; it also requires a deep fertile soil. Elm grows at first more quickly than beech, but afterwards it is liable to be passed, hence it must be placed in groups, or given a start. The groups should subsequently be underplanted with beech.

(7.) *Birch in mixture with shade bearing species.*—Such mixtures occur naturally. The light seed of the birch settles on all blanks, large or small, and too often interferes with the shade bearing species.

Birch and beech.—The birch should only form a moderate admixture by single trees; if it is more numerous, a part should be cut back. Birch becomes ripe for the axe long before the beech.

Birch and silver fir.—After some time the silver fir outgrows the birch, which is then likely to be suppressed.

Birch and spruce.—The birch injures the spruce by a whip-like action of its branches, but spruce soon passes and suppresses birch.

(8.) *Lime, aspen, and willow in mixture with shade bearing species.*—Like birch, these species appear naturally amongst shade bearers, more especially in beech woods, where they often do damage owing to their rapid growth in early youth. If it is desired to produce large specimens of these species, they must be reduced to moderate numbers. In after life, beech passes and suppresses them, if allowed to do so.

b. Mixture in Coppice with Standards.

The greater part of the mixture consists of broad-leaved species, but conifers (larch, Scotch pine, &c.)

are not excluded, so that an opportunity is given for the production of any or all species.

It must be a leading principle to let the light demanding species prevail in the standards or *overwood*, and the shade bearing species in the coppice or *underwood*. At the same time, some individuals of the latter species may be represented in the overwood, for the purpose of producing seed to meet the requirements of natural regeneration.

The overwood should consist of healthy trees which, if possible, have been raised from seed. Only in exceptional cases should vigorous coppice shoots be allowed to grow into standards.

In some cases all ages are mixed by single trees, in others the several age gradations are arranged in small groups. As the coppice shoots at once grow rapidly, seedlings have no chance of making their way up, unless they are strong, and are protected against the coppice shoots.

As each standard must be cut when it has reached the highest degree of usefulness, it follows that larch, Scotch pine, birch, and also ash will fall under the axe before the oak, elm, maple, or sycamore have reached a useful size; hence the former do not appear in the oldest age classes.

c. Mixture in Coppice.

The principal species are beech, hornbeam, elm, ash, maple, sycamore, lime, oak, sweet chestnut, birch, hazel, willow, aspen, etc.

Beech is more slowly growing than the light demanding species, and requires some protection against them

except on very fresh and fertile soils. Ash, Norway maple, sycamore, and oak are liable to suffer from too large a proportion of birch, hazel, and willow.

6. *Mixtures of Light demanding Species.*

As indicated above, such mixtures are justified only in exceptional cases. Generally, they are objectionable, as long as the admixture of a shade bearing species is practicable.

All mixtures of light demanding species thin out sooner or later according to the degree of light requirement and the tendency towards branch formation of the species, as well as according to the quality of the locality. When once that period has arrived, the factors of the locality must suffer. Exceptions are woods growing under favourable conditions, temporary mixtures and shelter-woods.

Generally, only the even aged form is admissible, and even then such mixtures require constant attention, so as to prevent one species being suppressed by the other.

a. Mixture in High Forest.

(1.) *Oak, with ash, elm, or sweet chestnut.*—These mixtures require a fertile, deep, moist soil and a favourable climate. Oak is slower growing during early youth, and in many cases also later on; hence it is liable to be suppressed. At any rate it rarely finds sufficient space for favourable development, being closely pressed by the other light demanding species. It does better if placed in groups.

(2.) *Oak with alder and birch.*—This mixture occurs on wet soil, where the oak occupies the drier parts of the locality.

(3.) *Oak with Scotch pine or larch.*—Such mixtures are made because oak helps to protect the Scotch pine against damage by insects, snow, etc., and larch against cancer, while Scotch pine and larch protect the oak during youth against frost and drought. If for the latter purpose, the mixture is frequently of a temporary nature, or only a few Scotch pines or larches are allowed to remain when the oak does no longer require shelter.

(4.) *Scotch pine with birch.*—This mixture occurs naturally, and yet it cannot be recommended, because such woods are always very thin and the soil deteriorates. They are generally the result ot unfavourable conditions in localities where no other species can compete with Scotch pine and birch.

Up to 15 or 20 years birch grows quicker; the Scotch pine, if it survives that period, comes up and passes it; the birch then requires help, if it is to be preserved. Birch falls under the axe at a comparatively early age, and an open wood of Scotch Pine remains. Only on good fresh soil does birch last until the Scotch pine has reached a marketable size.

At the same time birch may be a desirable admixture, where the object is to protect the Scotch pine against insects, snow, fire, etc., and where a more suitable mixture is impracticable.

(5.) *Scotch pine with larch.*—This mixture leads to unsatisfactory results whenever the locality is not thoroughly suited to larch. During youth, up to 15 or

20 years, larch grows quicker and may injure the Scotch pine. If the latter makes its way up and begins to press round or pass the larch, the latter must disappear.

Nevertheless, this mixture occurs over extensive areas in the United Kingdom, not because it is the best that can be devised, but because Scotch pine thrives well and yields higher returns than most of the shade bearing species which could be substituted for it.

Other mixtures, in which the Scotch pine is the principal species, are:—

Scotch pine with aspen or alder; not to be recommended.
" " " Weymouth pine; a good mixture.
" " " Austrian pine; the latter disappears, as it is slower growing.
" " " sweet chestnut; the latter often becomes a soil protection wood.

In England sweet chestnut is sometimes mixed with larch.

(6.) *Alder with birch and aspen.*—This mixture occurs in wet localities, where nothing else will grow.

b. Coppice, and Coppice with Standards.

Woods of coppice with standards consisting of light demanding species only, are comparatively rare, as the standards must either be very few in number, or the underwood suffers. Under any circumstances such mixtures require a very fertile soil. Mixtures of this kind are, for instance—

Ash and alder, or
Oak, sweet chestnut, ash, elm, and others; also hazel.

Where ash and alder appear in mixture, the former should, generally, be the overwood, and the latter the underwood; it occurs in wet localities. In fertile low lands oak appears as overwood and underwood, mixed with various other species, as ash, elm, etc. Short stems of the standards and injured underwood are often the characteristics of such mixtures.

Coppice woods coming under this heading are mixtures of oak, birch, lime, aspen, sallow, hazel, and more especially oak with sweet chestnut. In such mixtures Scotch pine and larch often find a temporary place as small standards.

Another mixture is that of sweet chestnut and acacia, generally by groups, or else acacia is likely to suffer.

CHAPTER IV.

THE SYLVICULTURAL SYSTEMS; OR, METHODS OF TREATMENT.

By a sylvicultural system is understood the systematically arranged method according to which the formation, regeneration, tending, and utilization of the woods, which compose a forest, are effected.

The character of each system depends in the first place on the method of formation or regeneration, and consequently all systems must come under one of the following three heads:—

(1.) High or seedling forest.
(2.) Coppice forest.
(3.) A combination of seedling and coppice forest.

Owing to the varying character in the factors of the locality, the composition of woods, and the many different purposes for which they are grown, the above three main systems have been split up into a number of variations. In the case of high forest the principal distinction is, whether the new wood is created on a clear cutting, or under the shelter of an existing wood. In the latter case, the regeneration may be effected at the same time in a uniform manner over a considerable area (compartment), or over certain groups, or by the removal of single trees here and there.

Coppice woods may consist of stool shoots or of pollards. Again, a number of auxiliary systems have been evolved out of the principal systems by means of certain modifications or additions.

It is not intended to describe here all existing modifications, but the more important systems may be classified as follows:—

I. Principal Systems:—

A. High or Seedling forest—

1. Clear cutting and subsequent regeneration 1
2. Regeneration under a shelter-wood:
   a. By compartments 2
   b. ,, groups 3
   c. ,, single trees 4

B. Coppice forest 5

C. Combination of seedling and coppice forest . 6

II. Auxiliary systems—

1. High forest with standards 7
2. Two-storied high forest 8
3. High forest with soil protection wood . 9
4. Forestry combined with the growth of field crops 10
5. Forestry combined with pasture . . . 11
6. Forestry combined with the breeding of deer and game 12

Section I.—Description of Systems.

In considering the various systems the following points deserve special attention:—

(1.) Origin and character of wood.
(2.) External dangers peculiar to the system.
(3.) Quantity and quality of produce.
(4.) Effect of the system upon the factors of the locality.

The remarks on each of the twelve systems will be arranged under these four heads.

1. *System of Clear Cutting in High Forest.*

a. Origin and Character.

The wood is originated on an area which is clear of trees by direct sowing, or planting, or occasionally by seed coming from adjoining woods. The young trees are all of the same age and height (or nearly so); as soon as the branches begin to interlace, the trees form an uninterrupted leaf canopy overhead, which, with advancing years, becomes more and more elevated above the ground, leaving a space below, in which the branchless trunks or boles of the trees tend upwards.

In a wood of this class the sunlight reaches only the upper parts of the crowns, the result being that height growth and the formation of clear boles are specially favoured. The density of the cover, and with it the diameter growth, depend on the character of the species, the quality of the locality, and the degree of thinning. At the end of the rotation the wood is cleared off the area, and the process of formation recommenced.

b. External Dangers.

The principal dangers are those of frost, drought, insects and storms. In early youth a wood formed on a cleared area is exposed to all meteoric influences. In winter, and especially in spring and autumn, frost threatens the young plants if they are at all sensitive to it, and in summer the uninterrupted exposure to the sun may dry up the soil and plants; they may also be seriously injured by a strong growth of weeds. Moreover, air currents strike over the area without interference. There can be no doubt that many diseases, which perhaps appear only later on, can be traced as having originated during this period of early exposure. At that time the greater dryness of the soil attracts insects, which concentrate their breeding places in it, while the absence of trees causes insect-destroying birds to be comparatively scarce.

Whether woods produced under this system are more subject to damage by storms than woods produced under shelter-woods is doubtful, varying views being held on the subject. On the one hand, trees of even age standing in crowded woods protect each other, but on the other hand individually they do not stand as firm as trees grown up in a more free position or in woods of uneven age. What has been said about strong winds probably also holds good as regards damage by snow and ice.

c. Production of Wood.

As regards production, the system compares favourably with other high forest systems, especially if the woods are created by planting. The quality of the

timber is also of a very high class if the thinnings have been judiciously carried out. More especially long clean non-tapering boles are produced under this system, to which a good diameter can be added by thinning strongly towards the end of the principal height growth.

d. Effect upon the Factors of the Locality.

This effect differs much during the several periods of the life of the wood. During early youth, before a complete leaf canopy has been established, the soil is exposed to the effects of sun and air currents, both of which act highly injuriously on the soil. Subsequently, when a good cover has been established, the very opposite effect is produced in a high degree. Later on in life again, when the crowns, with advancing age, have been elevated far above the ground, the sun is still kept out, but there is no impediment to air currents striking through the wood, so that moisture and carbon dioxide are carried away, and the activity of the locality is frequently considerably reduced by the time regeneration should be commenced.

It follows that the system has decided disadvantages where the supply of moisture is limited. At any rate, the production is subject to considerable fluctuations. In the case of shade bearing species with dense crowns, provided they are hardy, the system yields evidently much better results than in the case of light demanding species with thin crowns. The length of the rotation also affects the results.

2. *The Shelter-wood Compartment System.*

a. Origin and Character.

The wood is formed, or regenerated, under the shelter of the whole or part of the old crop, which forms the shelter-wood, and which is retained for some years until the young generation has established itself and is safe against injurious external influences peculiar to early youth. The regeneration is effected, according to circumstances, by the seed falling from the shelter trees, which in that case become mother trees, or by sowing and planting. In the former case the regeneration is said to be natural, in the latter artificial. In the case of natural regeneration, one seed year is rarely sufficient; as a rule two or three such seed years are required, and often artificial cultivation has to assist, in order to produce a full new crop; hence the latter shows in the majority of cases differences of age ranging up to perhaps 15 years. Nevertheless, such differences will be no longer discernible when the wood approaches the end of the period of principal height growth, and, for all practical purposes, such woods are considered even aged.

b. External Dangers.

Owing to the presence of the shelter-wood, the danger from frost, drought and weeds during youth is very considerably reduced, if not altogether obviated; during the rest of life no difference exists in this respect between this system and the system of clear cutting. There is no doubt that such woods are less attacked by insects than woods on clear cuttings. The chief difference as regards

storms, is that the shelter-, or mother trees, are liable to be thrown.

c. Production of Wood.

The quantity of total production is probably the same as in clear cutting. As regards quality it should be noticed that the mother trees are in a position to attain a specially large size (diameter), owing to their comparatively free position during the last period of life.

d. Effect upon the Factors of the Locality.

The unfavourable effect of sun and air currents during the early youth of the wood disappears under this system, as the shelter-wood protects the soil until the new crop can relieve it of this duty. In afterlife no difference exists between this system and that of clear cutting.

A modification of this system is the "Shelter-wood Strip System." Under this system each compartment is divided into a number of narrow strips, which are successively taken in hand for regeneration. The system is, however, otherwise precisely the same as the shelter-wood compartment system, the compartments merely receiving the shape of comparatively narrow strips.

3. *The Shelter-wood Group System.*

This is another modification of the shelter-wood compartment system.

a. Origin and Character.

The wood is formed, or regenerated, under the shelter of the old crop, but instead of taking a whole compartment in hand at one time, with a view to its simultaneous regeneration, only certain groups of trees scattered here and there over it are dealt with in the first place; when these have been regenerated, others are treated in the same way, and so on, until the whole compartment has been regenerated. The period of regeneration extends over not less than thirty, and often forty or fifty years, during which the old wood is gradually led over into the new wood. At the end of the regeneration period the new wood consists of a series of groups, of greater or smaller extent, ranging in age from one to thirty, forty, or fifty years, according to circumstances, and it presents a picture of unevenness which is preserved throughout life. The wood grows on until the next regeneration comes round, when operations are commenced in the oldest groups and gradually, in the course of thirty, forty, or fifty years, extended to the youngest.

During regeneration all seed years are taken advantage of, and artificial help, where necessary or desirable, is not excluded.

b. External Dangers.

Owing to the uneven age of the several groups, the young growth receives both top and side shelter; hence it is more fully protected against frost and drought than under the shelter-wood compartment system. It is also claimed for the system, that the trees withstand

storms and damage by snow or ice better. In this respect further data are required before a final conclusion can be arrived at.

c. Production of Wood.

Whether the total production is greater or smaller than under either of the previously mentioned two systems, can only be proved by actual statistics in the course of time; the system affords the means of producing valuable large timber, as, towards the end of the rotation, the finest trees can be placed comparatively free for a term of thirty to fifty years.

d. Effect upon the Factors of the Locality.

This is doubtless more favourable than under the shelter-wood compartment system, as the soil is more carefully sheltered, accompanied by a more complete preservation of an even state of moisture.

4. *The Shelter-wood Selection System.*

a. Origin and Character.

The forest is created, under the shelter of the old crop, by the removal of single trees or small groups selected here and there over the whole area, and this process goes on throughout the whole length of the rotation, so that practically no part of the forest is ever at rest. All age classes, from one year old to the oldest, are constantly represented, by single trees or small groups, over the whole area, and, theoretically, the work of selecting trees for cutting extends at all times over the whole

extent of the forest. In practice, however, the forest is divided into a number of blocks, which are gone over in turn, so that cutting returns to the same part only after the lapse of several years.

b. External Dangers.

Views differ somewhat regarding the extent to which selection forests are exposed to external dangers, as compared with the two previously mentioned shelter-wood systems. In the absence of exact comparative observations, it may be stated, that in respect of drought the selection system acts very favourably, because only very small plots are, at one time, exposed to sun and air currents. The same may be said, in the majority of cases, as regards frost. Nothing definite can be said in respect of damage by insects. As regards damage by wind, snow, etc., views differ.

c. Production of Wood.

Here again actual comparative observations are not available. It has by no means been proved that less wood per acre and per annum is produced under this than under either of the two previous systems. Young growth, no doubt, develops slowly, as it is much interfered with by the adjoining older trees, but this may be compensated for by a more active development when the trees have secured the full enjoyment of light, especially during the more advanced period of life. There can, however, be no doubt, that less clean and shorter boles are produced under the selection than under the compartment system, though the former is specially

suited for the production of large sized timber, as each tree can be left in the forest until it has reached the desired dimensions.

d. Effect upon the Factors of the Locality.

The system secures an almost absolutely equal degree of protection of the soil throughout the rotation, more especially as regards the preservation of an even degree of moisture, which must act beneficially upon production. Protection is given not only from above, but the uniform mixture of old and young trees also secures lateral shelter.

On sloping ground rain water is more effectively retained under this, than under any other system; avalanches also, the carrying away of fine earth, landslips, etc., are prevented; hence protection forests situated in mountains are usually worked under this system.

5. *The Coppice System.*

a. Origin and Character.

Most broad-leaved species have the faculty of reproducing themselves by shoots, which spring either from the roots, stool, or stem. After severing the whole, or part, of the stem above ground, the roots and stool develop shoots, which grow up into poles, and, under favourable conditions, into trees, thus producing a new generation. This process of regeneration can, as a rule, be repeated as long as the stool and roots continue to live.

When the trees are cut over close to the ground, *simple or ordinary coppice* is produced, the shoots starting

from a point which is close to, or in, the ground. Generally, several shoots spring from the same stool, and these stand in clumps, and can easily be distinguished from seedling trees. On well stocked areas a complete cover is established earlier under this system than in seedling forests, as the shoots develop very rapidly. When the cover has been established, the wood presents the appearance of an ordinary thicket in high forest.

If the trees are cut over at some height, say several feet, from the ground, the shoots appear at the upper end of the stem, which may be said to form a new crown. In that case the system becomes the *topping system* of coppice. If the main stems remain intact, or nearly so, and only the side branches are cut over, the method is called the *pollarding system*. No distinct line can, however, be drawn between these two systems, and in many cases topping and pollarding must be considered as synonymous terms. In either case the trees may be cut over repeatedly, just as in ordinary coppice.

b. External Dangers.

Coppice suffers more than seedling forest from late and early frosts, because the shoots grow up quickly, reach a considerable size during the first year, are full of sap, and consequently require a longer growing period in order to ripen before the autumn frosts set in. On the other hand, damage by frost is more easily repaired in the case of coppice, as new shoots will replace those injured during the first year. Coppice suffers also much more from damage by game, esp.:

deer. In respect of other sources of damage, coppice is less affected than high forest

c. Production of Wood.

Coppice yields chiefly firewood and small timber, such as pit timber, hop-poles, vine props, rafters, withies for basket work, &c. Oak coppice woods are cultivated for the sake of the bark, which is used for tanning. The production of cubic feet per acre and per annum is generally smaller than in the case of high forest.

d. Effect upon the Factors of the Locality.

Owing to the rapid growth of the shoots and the quick establishment of a complete cover, coppice woods protect the soil well after the first few years, but the latter is laid bare at much shorter intervals than in the case of high forest. The higher the rotation, the more nearly does coppice wood approach the character of high forest; as a rule, however, the rotation is short and the wood does not reach that age, at which air currents obtain free access underneath the crowns.

6. *Coppice with Standards (Stored Coppice).*

a. Origin and Character.

The system of coppice with standards is a combination of the following two systems:—

(1.) Simple coppice of even age.
(2.) Standards of uneven age treated under the high forest selection system.

The coppice forms the underwood, and the standards

the overwood, the two being treated under different rotations. Generally, cuttings are made in both under- and overwood at the same time, that is to say, when the underwood has arrived at the end of its rotation it is cut over, and at the same time those standards are removed which have reached the end of the rotation fixed for the overwood, or which it is desirable to remove for other reasons. New standards are then introduced, which, as a rule, should be seedlings and not coppice shoots. It follows that, theoretically, the several gradations of the overwood show a difference in age equal to one rotation of the underwood, and the age of the oldest standards at the time of cutting is a multiple of the number of years contained in the rotation fixed for the underwood.

Example.

Rotation of underwood . . . = 20 years.
Rotation of overwood . . . . = 100 „
Number of age gradations in overwood = $\frac{100}{20} = 5$.

At all times the youngest age gradation forms part of the underwood, until the latter is cut over.

Every standard removed at the end of the rotation must be replaced by younger trees. If all seedlings reached the end of the rotation, only one need be planted for every full sized standard which has been removed, but as numerous seedlings have, owing to various causes, to be taken out before the end of the rotation, it is necessary to plant several seedlings for every mature standard removed, so that, as a matter of fact, the numbers of the standards in the several age grada-

tions always form a falling series. The actual proportion of trees in each age gradation depends on circumstances. In the above mentioned example the proportion would be somewhat as follows:—

Number of age gradation .	I.	II.	III.	IV.	V.
Proportion of standards . .	20	12	3	2	1.

In other words, for every desired standard of 100 years old it is necessary to have 20 standards 20 years old, which will be reduced to 12 at 40 years, to 3 at 60 years, to 2 at 80 years, and to 1 at 100 years old. Though 38 standards are present on a certain area, only five reach maturity, the others being cut from time to time, thrown by wind or otherwise injured.

The actual number of standards per unit of area is governed by considerations for the underwood. If the standards are very numerous and give too much shade, the underwood will no longer thrive. In practice a great variety of modifications have been introduced, according to whether the overwood or underwood is more favoured.

The *normal form* is that in which over- and underwood receive equal attention. Here the effect of the shade thrown by the overwood must always be carefully considered; above all, the shade should be evenly distributed over the area. It is always desirable that the bulk of the overwood should consist of species with thin crowns, in other words of light demanding species.

Where *the overwood is favoured* the system approaches that of high forest. Here the object is to produce as much timber as possible, and the shade of the standards

would be so heavy, if evenly distributed, that the underwood could no longer thrive; hence it is desirable to place the over- and underwood into alternate groups. This will enable the underwood to thrive on the areas allotted to it, while the standards will produce straighter and cleaner boles than under the normal form.

If *the underwood is favoured* the system approaches that of simple coppice. The standards are here so far apart that they will not, as a rule, produce long timber unless they are brought together into groups here and there.

b. External Dangers.

These are very small when compared with those peculiar to most other systems. To begin with, the overwood is, at any rate in the normal form, capable of protecting the underwood against frost and drought. Under any circumstances such damage does not occur regularly and does not endanger the existence of the wood.

Storms do remarkably little damage in such woods. The younger classes of standards are protected by the older classes, and by the time they replace the latter they have developed strong root systems, so that they can hold their own.

Insects are not more destructive than in the shelterwood selection system, and less than in all other systems, which is due to the variety of stocking, absence of cleared spaces or loosened soil, and to the greater number of insect eating birds which are found in such woods.

c. Production of Wood.

It is probable that somewhat less wood is produced than under the high forest systems, but at any rate the

difference is not very great. On the other hand the system is specially adapted to the production of timber of all kinds and sizes. It affords opportunity for the individual development of the trees without endangering the factors of the locality. In one point, however, it is inferior to high forest, inasmuch as the shape of the trees is not so good; they are shorter and less clear of branches in the lower part of the stem.

d. Effect upon the Factors of the Locality.

If treated properly, coppice with standards acts highly beneficially upon the factors of the locality; the laying bare of the soil at the end of every rotation of the underwood is only very partial and of short duration.

7. *High Forest with Standards.*

a. Origin and Character.

During the regeneration of a high forest single trees or groups of trees are left standing with the intention that they shall continue to increase in size for a further series of years. After the completion of the regeneration, such woods consist of a new crop and a number of standards scattered over it, either in single trees or in groups. The period during which the standards are retained differs from a few years to a whole or even two or more rotations.

b. External Dangers.

These are the same as those of the original system, with this addition, that the standards are liable to be thrown by wind; hence only wind firm species should

be selected for standards, and the system should not be adopted at all in localities which are specially exposed to storms.

c. Production of Wood.

Under this system timber of very large dimensions is produced such as cannot be grown under any ordinary high forest system, except under exceptionally high rotations.

d. Effect upon the Factors of the Locality.

Directly, the effect is the same as that of the principal system. Indirectly the system acts beneficially, as it obviates the adoption of very high rotations where specially large timber is required.

8. *Two-storied High Forest.*

a. Origin and Character.

In the life of most woods, especially if they consist of light demanding species, a time arrives when the cover becomes interrupted, so that they can no longer preserve the factors of the locality. In the case of species where this time arrives at a comparatively early age a second crop can be introduced, generally by sowing or planting, which is allowed to grow up into high forest with and between the older crop, so that practically two distinct even aged woods exist on the same area, both high forest, the difference in age ranging from 20—60 years, according to species and circumstances; hence the name of two-storied high forest. The two crops are

cut over at the same time, when the whole process is recommenced.

It is usual to thin the older crop heavily, either before or after the introduction of the second crop, by removing all diseased and badly shaped trees, leaving those which promise to develop into fine sound timber trees.

The older crop should, in all cases, consist of light demanding and the younger crop of shade bearing species, or else the latter is not likely to thrive.

b. External Dangers.

The older crop may be subject to damage by storms, but generally only for a short period. Damage by frost in the case of the younger wood is excluded.

c. Production of Wood.

The system is well adapted for the production of large timber. During the first part of life the trees composing the upper storey grow up close together, developing height growth and clean boles; in after life they are placed comparatively free and can rapidly increase in diameter.

The system yields also an early and substantial return in the way of heavy thinnings of the older wood.

d. Effect on the Factors of the Locality.

The system preserves the factors of the locality better than ordinary high forest, and deserves to be extensively followed in cases where it is desired to produce large timber of light demanding species.

9. *High Forest with Soil-protection Wood.*

When the leaf canopy in a high forest begins to become interrupted, an underwood is introduced for the protection of the soil. Such an underwood must be dense and not too old, hence it must either be replanted from time to time, or, still better, coppiced periodically; it should consist of species which can stand the shade of the overwood, the latter consisting of thin crowned trees.

The effect on the factors of the locality is highly beneficial.

10. *Forestry combined with the Growing of Field Crops.*

The system of combining forestry with the cultivation of field crops is very old. Originally it consisted in cutting down a piece of forest, burning the wood, and using the land during one or more years for the production of field crops, and then allowing the forest to re-establish itself. As the value of forest produce increased some order was brought into the system in European countries; the timber, instead of being burnt, was utilized, only the twigs and other inferior pieces being burnt. The following are the two principal forms as now practised in Europe:—

a. Coppice combined with the Cultivation of Field Crops.

After each cutting over of the coppice wood the twigs and other valueless pieces of wood, together with turf, are burned. This process is effected either by distributing the brushwood evenly over the area and letting the fire run over it, or by mixing it with turf,

piling it up in heaps and burning after the material has become sufficiently dry. In either case the ashes are scattered, the soil is worked, and then used for one or two seasons for the production of field crops, which grow between the new coppice shoots.

It is said that with proper care the yield of forests so treated is not smaller than that of ordinary coppice woods. The returns from the field crops do rarely more than cover the outlay on account of labour, seed corn, etc.; hence the system is now restricted to hilly parts, where a sufficient area of permanent fields is not available, and where additional occupation for the existing population is wanted, the forest lands not being of sufficiently good quality to make their conversion into permanent fields desirable.

The species of tree which is most commonly cultivated in this manner is the oak, and next to it the birch and hornbeam, while Scotch pine is frequently brought in after the cultivation of cereals has ceased, to help in covering the ground and increasing the revenue.

The cereals usually grown are:—

Buckwheat — *Polygonum Fagopyrum* and *tartaricum*, L., and

Rye—*Secale cereale hibernum.*

The buckwheat is sown immediately after the clearing and burning, say in June, and harvested 6 or 7 weeks afterwards. The rye is sown in autumn and reaped in the following summer, when the cultivation of field crops ceases. In some cases the buckwheat and rye are sown together, the former being harvested in late summer of the first year, and the latter in the summer of the second year.

b. High Forest combined with the Cultivation of Field Crops.

After each cutting over of a high forest the soil is used for one or more years for the growth of field crops. The young forest crop is established, either at once, or after the growth of cereals has ceased, by sowing or planting in lines, or by sowing broadcast with the last crop of cereals. In some cases the soil is burned over after the clearing of the forest crop, as described in the case of coppice.

In addition to buckwheat and rye, frequently oats, potatoes, etc., are grown.

c. Effect of the System on the Factors of the Locality.

The two variations of the system are subject to the ordinary disadvantages of the clear cutting system, and in addition the cultivation of field crops may exhaust the soil. Hence, they are only permissible where they are an absolute necessity, or on soil which can bear the strain of clear cutting and of the growing of field crops without becoming exhausted. Where a crop of spruce or Scotch pine is to be immediately followed by a new crop of the same species, the burning followed by the cultivation of a field crop can be recommended wherever danger from insects is to be feared, the latter being destroyed or driven away by the burning.

The system is still extensively practised in India under a variety of names, as jhooming, dhya, kumri, taungya cultivation, etc. There the whole of the old crop of wood is generally burned, so as to obtain as large a quantity of ashes as possible. Of late years the practice has been taken advantage of in Burma to

produce young teak woods. The clearings are made in comparatively useless forest, the cultivators undertaking to sow or plant teak between their field crops, for which they are paid at an agreed rate at the end of the first, second, or third year.

11. *Forestry combined with Pasture.*

Pasture lands are widely planted with forest trees, which yield a certain return, and also improve the value of the pasture by keeping out cold or dry winds and by affording shelter to the cattle. Broad-leaved species may also be lopped for cattle fodder.

The trees are established by planting strong seedlings, which must be effectively protected against the cattle until the crowns have grown beyond their reach. The trees may be placed in lines.

12. *Forestry combined with the Breeding of Deer and Game.*

A forest which is fenced and stocked with deer or other game is called a preserve, or deer forest. The game as a rule interferes much with the production of trees, the latter being frequently the less important consideration.

High forest is usually preferable to coppice, because regeneration recurs only after longer intervals, and deer especially prefer coppice shoots to seedling plants; at the same time coppice woods suit most kinds of game better than high forest. Species which produce food for the deer, as oak, chestnut, etc., should be represented in deer forests.

Young growth must be carefully fenced; planting is preferable to sowing, as the object should be to reduce the regeneration period to a minimum.

Section II.—Selection of System.

It has been shown in the last section, that each sylvicultural system has its special advantages and disadvantages, and that their effects differ principally in respect of the production of wood, the power of resistance against external dangers, and the preservation of the factors of the locality. All these and many other matters must be considered in selecting the system which is best adapted to any special set of conditions. They may be brought under the following headings:—

(1.) Suitability of the system to the selected species.

(2.) The permanent preservation or even improvement of the factors of the locality.

(3.) Protection against external dangers.

(4.) Safety and simplicity of the method of regeneration.

(5.) Quantity and quality of the produce.

(6.) Intensity of management.

(7.) Existence or absence of forest rights.

1. *Suitability of the System to the selected Species.*

This is a consideration of the first importance in all cases where it is desired to grow a particular species. In the first place, coniferous species cannot be treated as coppice woods; while several broad-leaved species, such as beech and birch, possess only a moderate reproduc-

tive power by shoots. In all such cases only the high forest systems are indicated; beech and birch at any rate should not be grown in pure coppice woods. Again, light demanding species with thin crowns are but badly suited for ordinary simple high forest; they should be raised as standards in coppice with standards, or in two-storied high forest, or with a coppice underwood, or in mixture with shade bearing species. Such species are also difficult to raise under shelter-woods. On the other hand, tender shade bearers like beech and silver fir are better adapted to the shelter-wood systems than to the clear cutting system. Lastly, whenever a system involves two crops of uneven age on the same area, the overwood must consist of a thin crowned, that is to say, light demanding species, and the underwood of a dense crowned or shade bearing species.

2. *Preservation of the Factors of the Locality.*

On general economic principles, forests should be worked and managed for a sustained yield, and not for a temporary high return; hence it is necessary to select a system under which the factors of the locality are at least maintained, and if possible improved.

In the case of exceptionally good localities with a rich fresh soil and a favourable state of moisture and temperature of the air, any system can be adopted which answers to the other requirements of the case. On all localities of only middling quality, and still more so on poor localities, the first consideration must be the preservation of the factors of the locality, or else a steady deterioration will set in, which may end in com-

plete sterility. In such cases clear cuttings must be avoided as much as possible, and every effort made to keep the area permanently stocked with a crop of trees; in other words to regenerate under shelter-woods, so as to lead the old crop gradually over into a new crop. Unless this precaution is taken, the degree of moisture in the soil undergoes violent changes, which act most injuriously on production. The system best adapted in such cases is the shelter-wood selection system, the other shelter-wood systems which produce an uneven aged young wood, the shelter-wood compartment system and coppice with standards.

3. *Protection against External Dangers.*

It should be the object of a good management to produce healthy woods which are capable of resisting successfully the dangers to which they are exposed during life. Though species and method of regeneration are of principal importance in this respect, the system is also of some account.

Where the object is to counteract the eroding effects of water running down sloping ground, to prevent the occurrence of landslips, avalanches, or devastation through shifting sand, woods of uneven age must be the rule, such as are produced under the shelter-wood selection system, the group system, etc.

Whether uneven aged woods suffer less from wind, snow and ice than even aged woods is as yet an open question.

In respect of frost, drought and insects, the clear cutting system yields the worst results, the shelter-wood compartment system comes next, and then the

systems which produce uneven aged woods, the shelter-wood selection system being best of all.

On the whole, localities differ much; some rarely or never suffer from storms, snow, etc., while others do so every year. Such peculiarities must be taken into account in selecting the system.

4. *Safety and Simplicity of the Method of Regeneration.*

Whether the one or other method of regeneration is the more suitable depends on local conditions. In some cases artificial, in others natural regeneration by seed or by coppice is indicated. More especially the importance of shelter-woods in the case of middling and inferior localities must never be overlooked, as well as in the case of those which are subject to external dangers. Again, in some cases natural regeneration is easy, in others difficult or almost impossible, and a selection must be made accordingly. Another point is, that trees standing in an uneven aged wood produce, as a rule, more seed than those in an even aged wood. Finally, the system which acts most favourably in respect of the factors of the locality will also, as a rule, produce the most favourable germinating bed for the falling seed.

5. *Quantity and Quality of Produce.*

Woods yield timber, firewood and a variety of minor produce. As regards wood, a distinction must be made between timber and firewood. Where only the latter is wanted, that system is preferable which yields the largest volume or greatest weight of produce within a certain space of time. Where the objects of management

centre in the production of timber, other considerations prevail. Such production, if the timber is to be of any size, takes long periods of time, and it demands a continuous energetic action of the locality. More especially a continuously even degree of moisture in the soil has to be aimed at. Next, the proper amount of light must be given to each individual tree, in other words a sufficiently large and well developed crown. These considerations lead to the following conclusions:—

(*a.*) On fertile soil, with a sufficient degree of moisture, in the case of shade bearing species, and under moderately high rotations, the even aged systems yield satisfactory results, and their selection is justified.

(*b.*) On less fertile soils, which necessitate a careful husbanding of the factors of production, in the case of some of the species being light demanding, or under a high rotation, the systems of uneven aged woods are desirable.

The former produce principally long and clean timber, the latter greater girth.

In many cases the objects of management favour the production of minor produce, and the system must be selected accordingly. Where tanning bark of oak is wanted, the system of coppice is in its place. Osier beds require to be planted in cleared land. The growth of field crops also is only practicable under the system of clear cutting; at the outside, only a few standards may be left on the ground. Where grass and grazing is wanted the woods should be even aged, or else the cattle will damage the young trees, etc.

6. *Intensity of Management.*

The more valuable the returns of a forest are, the more intense, or careful and detailed, should be the system of management.

The capital invested in a forest differs considerably under different systems, it being composed of the value of the land plus the value of the growing stock, apart from buildings, etc., which would be required under any system. Hence, high forest requires a much larger capital than coppice, and often yields a smaller interest on the invested capital than the latter.

Artificial regeneration requires a periodical outlay of cash for sowing and planting, while natural regeneration can be effected without such outlay, though it may involve a considerable loss of time.

The transport of the material is considerably cheaper (up to 20 per cent.) in even aged woods than in uneven aged woods, because in the former case the operations are more concentrated. The same holds good as regards supervision.

The shelter-wood systems require more skilled labour than the clear cutting systems.

The uneven aged systems make much greater demands than the even aged on the intelligence and industry of the manager, because they require higher skill and more constant supervision. In the former case the executive charges must be smaller than in the latter.

7. *Existence or Absence of Rights.*

In many cases the existence of rights necessitates the selection of a particular system. For instance, where

large timber has to be provided to right-holders the coppice system would be inadmissible.

8. *Summary.*

Every sylvicultural system has its advantages and disadvantages, and it is necessary to ascertain in every special case whether the balance of the two tends towards the one or other system. *From a sylvicultural point of view*, the first point for consideration is the general suitability of the system, and next the continued preservation and, if possible, improvement of the factors of the locality; financial considerations should only prevail in so far as they do not interfere with the two former considerations.

INDEX.

A.

Absolute forest land, 20
Æsthetic effect of forests, 50
Afforestation, land available for, in Britain, 105
Air, atmospheric, 163
,, currents in relation to climate, 180
,, ,, protection against, 48
Alder in mixture with oak and birch, 258
Ammonia in air, 167
Area of forests, 54
Ash in mixture with oak, elm, and sweet chestnut, 257
,, ,, ,, shade bearing species, 254
Aspen in mixture with shade bearing species, 255
Assessment of quality of locality, 208
Atmosphere, the, 163
Avalanches, protection against, 48

B.

Beech, effect of, on locality, 206
,, in mixture with hornbeam, 246
,, ,, ,, silver fir, 245
,, ,, ,, spruce, 246
Birch in mixture with oak and alder, 258
,, ,, ,, Scotch pine, 258
,, ,, ,, shade bearing species, 255
Bole, definition of, 7
Britain, forestry in, 99
British Empire, forestry in, 91

C.

Capital of forestry, 16
Carbon dioxide, 165
Character of woods, 235
Chestnut, sweet, effect of, on locality, 207
,, ,, in mixture with oak, ash, and elm, 257
Clear cutting in high forest, system of, 263
Climate, 167
,, of India, 129
Communes, forests of, 79
Conifers, effect of, on locality, 207
Coppice, definition of, 10
,, mixtures of, 247, 256, 259
,, stored, 273
,, system, 271
,, with standards system, 273
Corporations, forests of, 79
Crowded woods, definition of, 9
Crown, definition of, 7

D.

Deciduous tree, definition of, 8
Deer and game breeding combined with forestry, 283
Development of forest trees, 216
Diameter growth of trees, 223
Direct utility of forests, 14

E.

Effect of forests, summary, 51
Elm in mixture with oak, ash and sweet chestnut, 257

Elm in mixture with shade bearing species, 254
Evaporation, effect of forests on, 43
Evergreen tree, definition of, 8

F.

Field crops, growing of, combined with forestry, 280
Final yield, definition of, 9
Financial aspect of forestry, 18
,, ,, ,, in Britain, 109
Forest, definition of, 5
,, Finance, definition of, 3
,, Law ,, ,, 3
,, Protection ,, ,, 2
,, Regulation ,, ,, 3
,, Utilization ,, ,, 2
,, Valuation ,, ,, 3
,, Vegetation, effect of, on locality, 203
,, ,, ,, of soil upon, 195
,, Working Plans, definition of, 2
Forestry, definition of, 4

G.

Game and deer breeding combined with forestry, 283
Great Britain and Ireland, forestry in, 99; conclusions, 115
Growing stock, definition of, 9

H.

Heat, 169
Height growth of trees, 219
High forest, definition of, 10
,, ,, two storied, 278
,, ,, with soil-protection wood, 280
,, ,, ,, standards, 277
Hornbeam, effect of, on locality, 206
Hornbeam in mixture with beech, 246
,, ,, oak, 254
,, ,, Scotch pine, 251
Humidity of the air, 38
Hygienic effect of forests, 49

I.

Imports of forest produce into Britain, 101
,, ,, ,, British Empire, 92
Increment, definition of, 9
India, area of forests in, 142
,, climate and rainfall of, 129
,, distribution of forests in, 140
,, financial results of forestry in, 152
,, forest poling in, 144
,, forestry in, 125
,, physical configuration of, 126
Indirect utility of forests, 27
Intermediate yield, definition of, 10
Ireland, forestry in, 99

L.

Labour in forestry, 24
Larch, effect of, on locality, 208
,, in mixture with beech, 250
,, ,, ,, oak, 258
,, ,, ,, Scotch pine, 258
,, ,, ,, silver fir, 250
,, ,, ,, spruce, 248
Layer, definition of, 7
Life, duration of, of trees, 226
Light, 174
Lime tree, effect of, on the locality, 207
,, ,, in mixture with beech and other shade bearers, 257

Locality, assessment of quality of, 208
,, effect of forest vegetation on the, 203
,, in relation to forest vegetation, 162

M.

Major produce, 9, 14
Maple in mixture with more shade bearing species, 254
Mechanical effect of forests, 45
Methods of treatment, 261
Minor produce, 9, 15
Mixed wood, definition of, 9
,, woods, 237
,, ,, advantages of, 238
,, ,, disadvantages of, 240
,, ,, rules for the formation of, 241
Moisture in air, 38, 165
,, ,, relation to climate, 178

N.

Nitric acid, 167
Normal growing stock, definition of, 17

O.

Oak, effect of, on locality, 207
,, in mixture with alder and birch, 258
,, ,, ,, ash, elm and sweet chestnut, 257
,, ,, ,, beech, 252
,, ,, ,, hornbeam, 254
,, ,, ,, Scotchpine and larch, 258
,, ,, ,, silver fir, 252
,, ,, ,, spruce, 251

P.

Pasture combined with forestry, 283
Peculiarities of forestry, 21
Poles, definition of, 8
Precipitation, effects of forests on, 4
Principal produce, 9, 14
Private forests, supervision of, 83
Protection forests, 67
Pure wood, definition of, 8
,, woods, 235

Q.

Quality of locality, assessment of, 208
,, ,, ,, definition of, 10

R.

Rainfall, effect of forests on, 40
,, in India, 129
Reproductive power of trees, 229
Rivers, feeding of, 45
Rotation, definition of, 9

S.

Scotch pine in mixture with birch, 258
,, ,, ,, larch, 258
,, ,, ,, oak, 258
,, ,, ,, shade bearing species, 250
Seedling, definition of, 7
Selection system, 284
Shade-bearing species in mixtures with light demanding species, 247
,, ,, mixtures of, 244
Shape of trees, 216
Shelter-wood compartment system, 266
,, group system, 267
,, selection system, 269
Shrub, definition of, 7

Silver fir, effect of, on the locality, 207
,, ,, in mixture with beech, 245
,, ,, ,, larch, 250
,, ,, ,, oak, 252
,, ,, ,, spruce, 245
Soil, 181
,, classification of, 191
,, composition of, 184
,, effect of, on forest vegetation, 195
,, formation of, 182
,, origin of, 182
,, physical properties of, 189
,, protection of, 46
,, protection wood in high forest, 280
,, sufficient depth of, 195
,, suitable chemical composition of, 198
,, ,, degree of moisture of, 197
,, ,, ,, porosity of, 197
,, summary of demands of species on, 201
Solid bodies in air, 166
Space required by trees, 216
Species, ruling, 159
,, dependent, 159
Springs, feeding of, 45
Spruce, effect on locality of, 207
,, in mixture with beech, 246
,, ,, silver fir, 245
,, ,, larch, 248
,, ,, oak, 251
Standards, coppice with, 10, 273
,, ,, mixtures of, 255, 259
,, high forest with, 277
State forests, 71
,, the, in relation to forestry, 57
Stool, definition of, 7
,, shoot, definition of, 7
Stored coppice, 273
Sucker, definition of, 7
Supply of forest-produce, uncertainty of, 112
Sycamore in mixture with more shade bearing species, 254
Sylviculture, definition of, 3
,, *foundations of, 155*
System, selection of, 284
Systems, sylvicultural, 261

T.

Temperature of air, effect of forests on, 29
,, ,, soil, effect of forests on, 35
Thicket, definition of, 7
Thin wood, definition of, 9
Tree, definition of, 6
Trees, development of, 216
,, duration of life of, 226
,, reproductive power of, 229
,, shape of, 216
Two-storied high forest, system of, 278

U.

Utility of forests, 11

V.

Volume growth of trees, 224

W.

Willows in mixture with shade bearing species, 255
Woods, character and composition of, 235
,, mixed, 237
,, pure, 235

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